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# USING ABSOLUTE PROBABILITY JUDGEMENT METHOD FOR HUMAN RELIABILITY ASSESSMENT - A CASE STUDY

**Abstract:** *Human reliability assessment is becoming increasingly important in risk assessment in all industrial systems. All methods for human reliability assessment are used to estimate human error probabilities, which is a measure of human reliability. Human error assessment is certainly a challenge for all the experts involved in risk assessment today. In Serbia, this issue has not received proper attention yet. Therefore, this paper presents the case study which confirmed that the usage of Absolute Probability Judgement for proper human reliability assessment. This approach was used in a case study of the Electric Power Company in Serbia (hereinafter EPCS) for the purpose of the analysis accident of a repair intervention on a 10/0.4 kV steel lattice tower "Nova Kolonija" (jurisdiction of EPCS, Veliki Trnovac, ED "Jugoistok", Nis, Serbia). The case study performed at the EPCS has confirmed that the conventional APJ approach is not only highly applicable for quantification of human errors, but also comprehensive and simple to use in risk assessment of complex systems.*

**Key words:** Absolute Probability Judgement, Human Reliability Assessment, Accident, Case Study

## INTRODUCTION

Human Reliability Assessment (hereinafter HRA) is a hybrid area, arising out of the technical disciplines (reliability engineering) on the one hand, and psychology and ergonomics on the other. The analysis of complex systems of various industrial activities (electric power industry, mining, aviation, petrochemical industry, etc.) has proved that human error is the most common cause of accidents.

A review of literature shows that "human factor" was the cause in 80% of major accidents in the past (e.g. Chernobyl, Bhopal, Three Mile Island, etc.) and a crucial factor in around 90% of occupational injuries. Consequently, Stary (1998) emphasizes the importance of managing "internal and external human factors" that can contribute to errors in a system, leading to occupational injuries and damage to natural resources and material wealth (Stary, 1998). Success of any organization depends on how well they control behaviour of their employees, while safety managers should be focused on the "human error" as the biggest individual source of operative errors (Petersen, 2001).

The term human error has been pragmatically defined by Swain (1989) as follows: "any member of a set of human action or activities that exceeds some limit of acceptability, i.e. an out of tolerance action where the limits of performance are defined by the system" (Swain, 1989). Dhillon (2009) defines the human error as "a failure to perform some specific task that could result in disruption of scheduled operations of damage to equipment and property"(Dhillon, 2009).

Main problem in formulating a comprehensive definition of human error lies in the fact that these errors are often the result of a complicated sequence of events. Human error is considered to be the cause of accidents and failure in the functioning of the system based on the traditional approach, while the modern approach is a different view on human error, suggesting that error is a result of a deeper issues within the system, mainly of relations between people, tools, tasks and the work environment (Dekker, 2002; Woods, et. al, 2010).

Industrial studies of accidents are the ideal source of data on human error. Other sources are simulation data and data derived from literature on human performance. However, there are many difficulties in obtaining such information: difficulties in estimating the number of possibilities in which an error occurs in complex tasks, reliability of 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. (Stojiljković, 2011). The complex issues like these demanded the approach that does not rely on the data, but on the use of expert opinion.

In a number of foreign and domestic research papers, methods used to assess human error based on expert assessment are analyzed. These are the following methods: Absolute Probability Judgement - APJ; Human Error Assessment and Reduction Technique -

HEART; Technique for Human Error Rate Prediction - THERP; Success Likelihood Index Method - SLIM; Influence Diagrams Approach - IDA; Human Cognitive Reliability - HCR; Technica Empirica Stima Errori Operatori - TESEO, etc.

Evaluation of these methods was based on the evaluation of the following quantifiers: accuracy, validity, usefulness, effective use of resource, acceptability and maturity. The best rated methods are HEART, APJ, THERP, SLIM, slightly lower rated methods are PC and IDA, and the lowest rated are methods TESEO and HCR (Kirwan, 1988, 1994, 1995).

Second and third generations of human reliability assessment methods are developed to overcome the deficiencies of the previous generations. Second generation methods are A Technique for Human Error Analysis - ATHEANA, Cognitive Reliability and Error Analysis Method - CREAM, Method for the Performance of Safety Operation - MERMOS, Cognitive Environmental Simulation - CES and Connectionism Assessment of Human Reliability – CAHR. Methods of third generation are in fact improved version of methods from previous generation and the only one developed so far is Nuclear Action Reliability Assessment – NARA which is in fact a modified HEART method (Di Pasquale et al, 2013).

All methods for the human reliability assessment are used to estimate Human Error Probabilities (hereinafter HEP), which is a measure of human reliability. For quantification of Human Error Probabilities in the Electric Power Company in Serbia (hereinafter EPCS), the expert team had a few meetings in order to choose the suitable methods for the mentioned type of assessment. Following four methods, APJ, HEART, THERP and SLIM were chosen as appropriate for the HRA in EPCS.

The research comprised the analysis of 1074 workplaces with a total of 3997 employees in terms of their age: up to 20 years of age (6); between 21 and 30 years old (280); between 31 and 40 years (1120); between 41 and 50 years (1376); between 51 and 60 years (1131); and between 61 and 65 years old (84). The numbers of employees by the level of education was as follows: level I - 140, level II - 87, level III - 1009, level IV - 1355; level V - 667; level VI - 268; level VII-1 - 462; level VII-2 - 7; and level VIII - 2.

Testing of these methods (APJ, HEART, THERP and SLIM) has lead to a conclusion that APJ has a great potential for HEA, therefore, this method was used in a further work.

The expert team, experienced in the field of HRA, had appropriate knowledge of all sectors, activities, and procedures within EPCS. Most of them were with over 20 years of professional experience and some were the direct executives of the Risk Assessment Project that was implemented in EPCS.

At the following meetings, expert team considered various aspects for implementation on APJ within the EPCS. Eventually, it was concluded by the authors of this study that application of APJ, which is a simple and straightforward method, in the framework of such complex system as EPCS can be a very demanding task. Main reasons for these are wide variety of workplaces and extremely large number of employees. Having this in mind the expert team decided to develop methodology based on the APJ concept, that will make human error quantification process much easier and quicker (see more: Stojiljkovic, et al. 2016).

Previous consideration of accidents in the EPCS indicated that the largest number of accidents occurred at 10/0.4-kV steel lattice towers. Therefore, the expert team has focused their attention on this object in order to identify human errors. For the purpose of this study, a database on work-related injuries, accidents and critical interventions that occurred over a ten-year period has been developed.

## METHODOLOGY

The APJ is, as a concept, the simplest approach to quantification of human errors since it is based on the assumption that people can directly assess their likelihood of an event, in this case, a human error (Kirwan, 1994, 1995; Grozdanovic, et al., 2005; Grozdanovic, 2005). When it comes to risk assessments for existing plants or systems, it is arguable that the more experienced personnel will have a reasonable memory of their own errors, as well as of other operators' errors and their rates of occurrence.

There are two basic APJ approaches. In a "single expert APJ", only one expert needs to assess the probability of a human error. Kirwan (1994) emphasized the importance of group evaluation, in order to reduce the subjectivity of the assessment. He also identified four types of aggregations of individual judgments in the "group APJ" (Kirwan, 1994):

- Aggregated individual method - this method entails that the experts do not meet but make estimates individually. These estimates are then aggregated statistically by taking the geometric mean of all the individual estimates for each task.
- Delphi method - experts make their assessments individually and then all the assessments are shown to all the experts.
- Nominal group technique - this method is similar to the Delphi method, but after the group discussion, each expert makes his or her own assessment. These assessments are then statistically aggregated.
- Consensus-group method - in this method, each member contributes to the discussion, but the group as a whole must then arrive at an estimate upon which all members of the group agree.

All forms of APJ, whether group or individual, are prone to particular biases which can detract from the accuracy of the experts' assessments. One of the major ways to reduce the problem of biases in expert judgment is employing a facilitator during the experts' group session. The primary function of the facilitator is

to try to overcome these biases. Therefore, a secondary function of the facilitator is to overcome any personality conflicts, or other problems, which may occur in small groups, and influence the assessment process.

The APJ procedure consists of 7 steps (Figure 1) which are described in detail in the research papers (Seaver & Stillwell, 1983; Comer et al., 1984; Kirwan, 1994; Grozdanovic, 2005; Stojiljković, 2011; Stojiljkovic, et al., 2012; Stojiljkovic, et al., 2016).

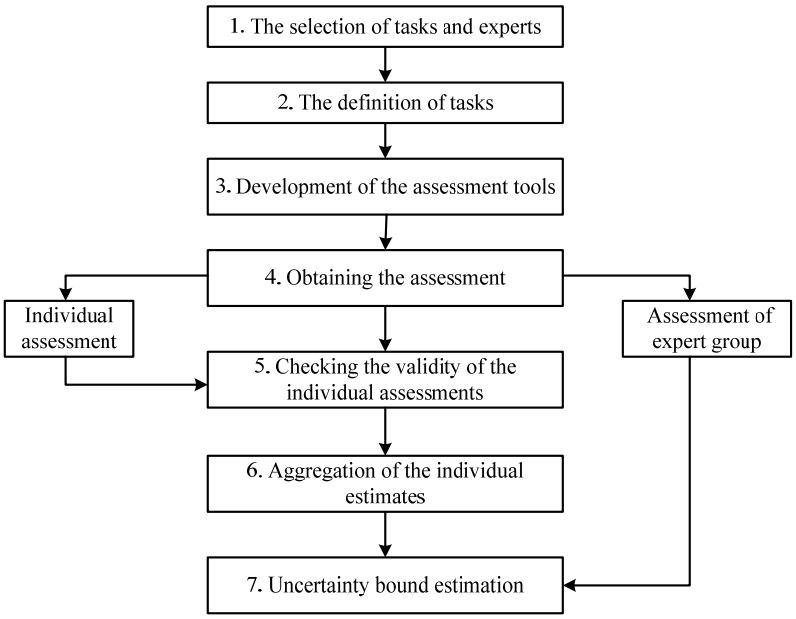


**Figure 1.** *Procedural steps of the APJ method*

## RESULTS AND DISCUSION

In the following text, Absolute Probability Judgement method was used for human error quantification in the case study of a repair intervention on a steel lattice tower 10/0.4 kV "Nova Kolonija" in EPCS (jurisdiction of EPCS, Veliki Trnovac, ED "Jugoistok", Nis, Serbia), which resulted in an accident.

One of the aims of this study is to show the necessity of human error assessment not only in manufacturing industries but, as it will be shown in this paper, in companies that distribute electric energy, as well. An assessment of ten typical human errors was made by ten experts.

Figure 2 shows the values of *HEP* using the APJ method for human error assessment in the case of a repair intervention on a steel lattice tower 10/0.4 kV "Nova Kolonija" in EPCS.

Individual HEP estimates were used because a reasonable level of agreement between the experts has been achieved (correlation coefficient K>0.5 confirms the consent of the expert opinion). To make the subsequent calculation easier, the set of HEP obtained from the expert is then transformed into their logarithmic equivalents (see more: Stojiljković, 2011; Stojiljkovic, et al., 2012; Stojiljkovic, et al., 2016).

The experts had an insight into the scale for estimating the probability (Stojiljković, 2007), database on human errors (Stojiljković, 2011) and Risk Assessment Act in the workplace and working environment in ED "Jugoistok", Nis, Serbia.

Ranking the probabilities for the occurrence of human errors that is given in descending order indicates which errors in particular should be considered, for the purpose of their elimination or reduction. The order of the probabilities (given in brackets) of occurrence of human errors in this EPCS case study is as follows:

- Absence of job authorization and Failure to use the prescribed tools ($9.4\ 10^{-2}$),
- Breach of field operation protocol ($2.9\ 10^{-2}$),
- Erroneous routine operations which require meticulous attention and Inadequate cooperation between operators ($9.2\ 10^{-3}$),
- Improper and imprecise issue of a job order and Incomplete implementation of safety measures on the job site ($7.9\ 10^{-3}$),
- Failure to implement the fundamental principles of job organization and Failure to use the prescribed equipment for personal safety ($9.3\ 10^{-4}$),
- Communication error ($9.2\ 10^{-4}$).

In the case study, human errors with the highest probability are: failure to use the prescribed tools and absence of job authorization, then the following: breach of field operation protocol; inadequate cooperation between the operators and erroneous routine operations

which require meticulous attention; improper and imprecise issue of a job order and incomplete implementation of safety measures on the job site; failure to implement the fundamental principles of job organization and failure to use the prescribed equipment for personal safety, whereas communication error is of the lowest probability.

Implementation of APJ method in EPCS and the achieved research results contribute to:

- Operator reliability, reducing human error occurrence and increasing awareness on significance of occupational safety, health and environmental protection measures;
- Improvement of occupational safety standards by preventing occupational injuries and fatalities, increase in productivity, and decrease in lost working hours and expenses;
- Improvement of environmental protection standards through reduction of damage in electric power plants, reduction of environmental pollution and substantial economic loss, preservation of natural and material wealth, and prompt and adequate emergency response.

On the basis of all the above mentioned, it can be concluded that the APJ has application in EPCS, i.e. in companies for the distribution of electric energy. Successfully applied APJ for human reliability assessment in EPCS, based on an analytic-synthetic approach, could be implemented in other industrial sectors too.

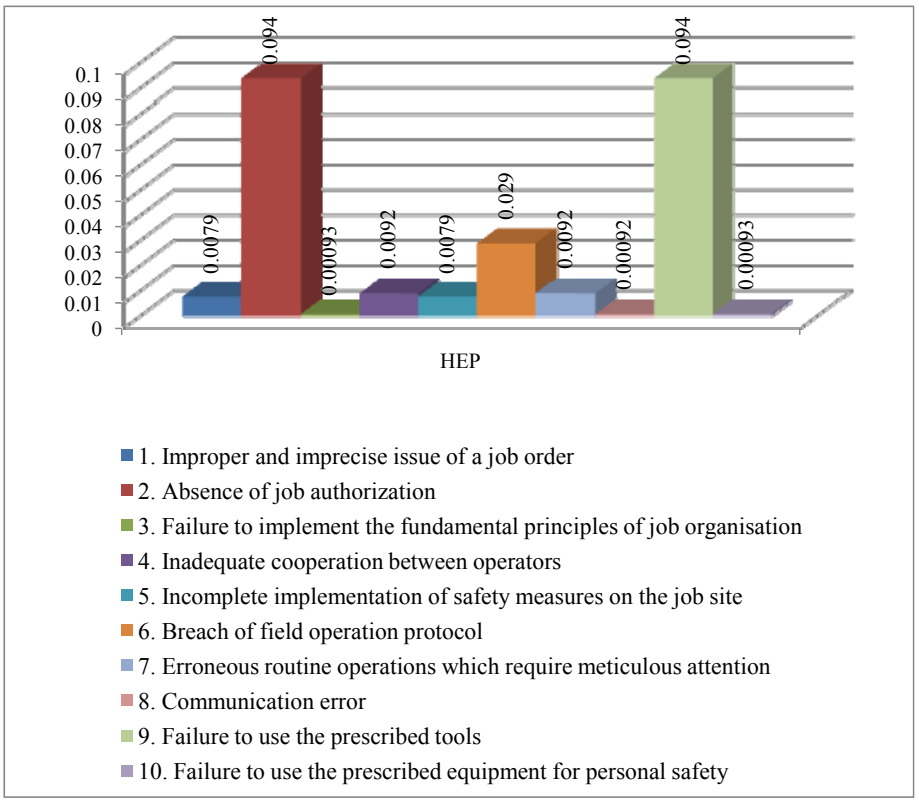


**Figure 2.** *Values HEP using the methods APJ for HRA in the case study in EPCS*

## CONCLUSION

Methods for the human reliability assessment began to develop intensively after numerous accidents which were caused by human error or inadequate activity of people who controlled and managed complex technological processes. The APJ approach is conceptually the most straightforward HRA approach.

The APJ uses a group of experts for assessment of human error probability and for indication of the contradictions of the analyzed process. The APJ is the simple to use, however, it is important to carefully select experts, since lack of motivation and/or excessive self confidence can influence early conclusion, which can undermine the APJ method validity. The APJ is prone to certain biases, as well as to personality group problems and conflicts, which, if not effectively countered (e.g., by a facilitator), can significantly weaken the validity of the technique.

Although the APJ method does not consider the performance shaping factors related to the operator and the environment, and the fact whether those factors have positive or negative impact on the operations, the task of the experienced experts is to provide the interpretation of measures for improvement.

In modern companies for transmission and distribution of electricity, in addition to demands for continuous, stable and electric energy supply of standard quality, it

is essential to implement the appropriate working control and management. In case of EPCS, all company authorities, higher and lower management, as well as workers on the terrain were informed in an appropriate manner about the findings of this research. Results obtained in this case study (implementation of APJ for HEP in a repair intervention on a steel lattice tower 10/0.4 kV "Nova Kolonija"), according to the positive feedback from the EPCS, contribute to reducing human error, increasing operator reliability, increasing awareness on significance of occupational safety, as well as health and environmental protection measures.

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# PRIMENA METODE APSOLUTNE VEROVATNOĆE PROCENE ZA PROCENU LJUDSKE POUZDANOSTI - STUDIJA SLUČAJA

***Evica Stojiljković, Bojan Bijelić, Marko Cvetković***

**Rezime:** *Procena ljudske pouzdanosti postaje sve značajnija prilikom procene rizika u svim industrijskim sistemima. Sve metode za procenu ljudske pouzdanosti zasnivaju se na izračunavanju verovatnoće ljudske greške, koja je mera ljudske pouzdanosti. Procena ljudskih grešaka svakako je izazov za sve stručnjake koji se danas bave procenom rizika. U Srbiji pitanje pouzdanosti ljudskog faktora još uvek nije dobilo adekvatnu pažnju. Zbog toga je u ovom radu predstavljena studija slučaja koja se odnosi na primenu metode Apsolutne verovatnoće procene (APJ) za procenu ljudske pouzdanosti. Koncept APJ korišćen je u Elektroprivredi Srbije u cilju analize akcidenta do koga je došlo prilikom intervencije na čelično-rešetkastoj TS 10/0,4kV „Nova Kolonija“, Veliki Trnovac, ED „Jugoistok“ Niš. Studija slučaja sprovedena u Elektroprivredi Srbije potvrdila je da konvencionalni APJ pristup nije samo primenljiv za kvantifikaciju ljudskih grešaka, već i sveobuhvatan i jednostavan za korišćenje u proceni rizika kompleksnih sistema.*

**Ključne reči:** Apsolutna verovatnoća procene, Procena ljudske pouzdanosti, Akcident, Studija slučaja.