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Human errors monitoring in electrical transmission networks based on a partitioning algorithm

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ABSTRACT

Operational experience from electrical transmission networks has demonstrated that human error represents a key factor in operating inefficiencies, equipment damage, and accidental incidents. The awareness of the importance of human factor has increased significantly over the last few years primarily owing to the fact that some major incidents have had significant human error contributions. The analysis of these incidents has led to recognition of the fact that more information about human actions and errors is needed to improve the safety and operation of electrical transmission networks. Thus, power grid companies are placing renewed emphasis on approaches to prevent the occurrence and limit the effects of human errors. This paper analyzes human errors in the electrical transmission networks of the Romanian Power Grid Company. It is important to understand how human operators supervise these networks and the challenges they face in the monitoring task. In the paper an analysis of incidents related to human errors, over a time span of 10 years (2000–2009) was performed. The analysis is based on partitioning the electrical transmission network of Romania using a clustering method. The aim is to provide design engineers with a better understanding of the electrical network operation so that they can respond to the needs of the operators in when new human–machine interfaces for monitoring tasks are implemented.

1. Introduction

The networks that enhance our quality of life are increasingly becoming more complex in size, speed, and functionality as technology advances. Because these networks are interdependent, the whole infrastructure is built upon underlying computerized systems that are interconnected; they cannot be studied completely in isolation [1]. The dimensions of these complex networks can lead to multiple implications for the human factor.

Studies on human error monitoring in complex systems (i.e. water distribution systems, electrical power grids, air traffic control, and nuclear power plants) revealed that they are prone to adverse consequences because human cognitive abilities to perceive, understand, decide, and react do not scale in the same way as network size, speed, and functionality. A frequent statement is that it is impossible to eliminate human error from complex systems since man is by nature subject to error [2,3]. Another interesting approach correlates the human error, the complexity of the task, and the experience of the operator, whereby the probability of human error increases when an inexperienced operator executes complex tasks. The relationship between human errors, operator experience, and complexity of the task is presented in Fig. 1 [4].

The term "human error" is loaded and very ambiguous. Thus, a human error is committed if the effect of human behavior exceeds a limit of acceptability. But, the classification of a specific behavior as an error depends as much upon the limits of acceptability as it depends upon the behavior itself [5]. In [6] the following definition for human errors is given: "Any action (or inaction) of the human factor that potentially or actually results in negative system effects". The analysis of human error data requires human error classification. Thus, each erroneous action or inaction by each person involved should be classified separately. This ensures that a database can provide an accurate account of the numbers and types of errors in any incident.

This paper proposes a new approach for monitoring human errors based on partitioning/division of the electrical transmission networks into coherent and completely connected clusters (named zones). The remainder of this paper is organized as follows. Section 2 presents an overview of the technical literature on the problem of human errors in power systems, synthesizing the existing approaches and providing the rationale for developing the proposed method. Section 3 illustrates the formulation of the problem of monitoring human errors based on the partitioning of electrical transmission systems and its solution using a clustering algorithm. Section 4 shows the results of testing the proposed method on the

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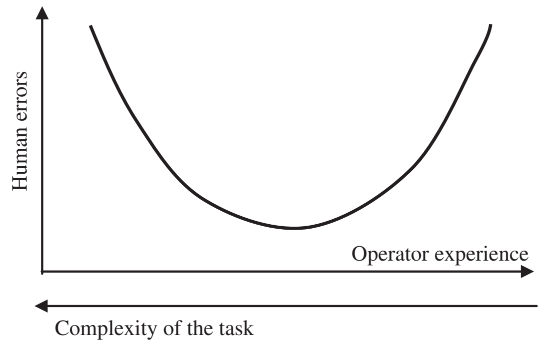

Fig. 1. Relationship between human errors, operator experience, and complexity of the task.

Table 1
The factors that contribute to human errors [10].

No.	Factors	Description
1	Competency	Knowledge of the job, skills and attitude towards the job
2	Communication	The ability to express information
3	Procedural factors	Clarity regarding standards and procedures and whether they are adhered to
4	Mental and physical factors	Stress and cognitive overload and exhaustion
5	Socio – environmental factors	Personal pressures such as family pressures and organizational pressures such as work relations
6	Motivation	Individual and organizational aspects like job satisfaction and leadership style
7	Ergonomical factors	Light, noise, space, etc. This included health, safety, and shift cycles

Romanian electrical transmission system. Section 5 contains the concluding remarks.

2. Aspects regarding human errors in power systems

When supervising any power system, operators view and synthesize multiple data sources. Operators must be capable of reacting to network changes rapidly to minimize negative effects on the system. When operators fail to react to changes in a timely fashion, cascade effects can occur [7,8]. A representation of the human behavior can be made using a human event tree, Fig. 2.

The human errors can occur in the operation of technical systems for a number of reasons. Errors can be directly attributed to technical system design, environmental, and human factors. While the technical system design can be controlled to eliminate and/or reduce human error occurrence, the control of environmental factors and the way the system is used by personnel is often less controllable [9].

Theories about the human errors, and practical approaches for analyzing and managing errors, have largely been developed in many industries such as chemical and nuclear power processing. In these industries the effects of human error have already resulted in numerous incidents and catastrophic accidents. The incidents occur because human factors interact with this infrastructure, so human performance plays an important role in its efficiency and security. Generally, the factors that may contribute to human errors are presented in Table 1 [10].

In all cases the human error classification is used to assist the analyst to achieve his or her own objectives. Because different objectives can be used for the analysis of human behavior, there are many different ways of classifying human errors.

The classifications vary considerably depending on whether it has been developed from a theoretical psychological approach to understanding human behavior or error, or whether it has been based on an empirical practical approach. In [11], the human errors were classified in errors of omission and errors of commission. The former implies missing one or more steps in a procedure and the latter implies that a different procedure was used. The main issue in both of them is that the human operator is unconscious of the error. The human operator believes that the procedure is complete (in errors of omission) or better than the original procedure (in errors of commission). Another classification of human errors is given in [5], where errors were classified as random errors, due to the random variability of human performance such as variations in manual precision or force; differences in timing and simple mistakes and slips of memory; as systematic errors which can be caused by personal abnormalities or inappropriate system design; and, finally, sporadic errors, occasional "faux pas" which are infrequent and often unexplainable erroneous actions. From this definition it follows that it is difficult to give general characteristics of sporadic errors.

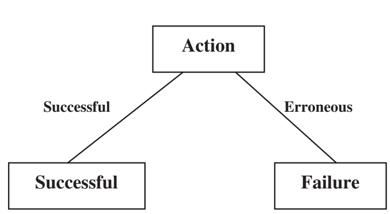

Fig. 2. Simplified representation of the human event tree.

As a consequence, complex systems must be operated with the recognition that breakdowns in operation will occur as a result of human error. Thus, specific defenses in the design, operation and personnel selection and training must be applied to minimize the occurrence and limit the consequences of human error. Equipment design and interfaces which minimize the potential for misunderstanding and control interference, and support recovery from errors, will promote reliable system performance [9].

In the power systems, the operators have many tasks in their daily monitoring of the grid. The three main monitoring tasks in electrical power grids are [1]:

- Monitoring sensors data from power grid components (bus voltages, bus numbers, status of the capacitors, transmission lines, transformers, circuit breakers, etc.).
- Monitoring the grid as a holistic system.
- Responding to alarms.

Operating errors are identified as being errors made by operators, which constitute the main causes of human error. The following situations lead to operating errors [11]:

- Lack of proper procedures.
- Task complexity and overload conditions.
- Poor personnel selection and training.
- Operator carelessness and lack of interest.
- Poor environmental conditions.
- Departure from following the correct operating procedures.

It has been recognized that safety management, loss prevention and error reduction can be improved by the systematic use of human error data. The electricity companies are interested in the discovery, collection, classification and understanding of incidents for the purpose of developing specific error reduction strategies. In particular, they wish to improve the work organization and performance of the operators. The main sources of data can be [12,13]: