Evaluation of the Influence of the Human Factor on the Reliability of the Information and Control Systems in the Electric Power Industry

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Abstract – **In the article, there are presented the methods for evaluation of the reliability of the information and control systems of the dispatch station in the electric power industry, having into consideration the reliability of the human factor. There are examined several actual up-to-date methods of approach for the optimization of the influence of the human factor on the safety in such complex systems. There are analyzed the factors acting to the reliability of the human-operator and are suggested generalized criteria for their evaluation.**

Keywords – **Reliability, Information and Control Systems, Human Factor, Electric Power Industry.**

I. Introduction

The up-to-date techniques and technologies (from the automobile to the Nuclear Power Plant) are characterized with a high degree of automatization, availability of information systems for receiving and processing of operational information for the working parameters of all main elements and units and the running of the processes as a whole.

The energy systems with their various equipment, huge number of sub-systems and complex connections between them are a natural object for application of a hierarchical approach in the development of their organization and management, including a wide spectrum of activities for organization, planning, control, constructing, assembly, operation, maintenance and development of information systems and technologies. In the up-to-date organization of the production of electrical energy and its supply and distribution by access and transportation systems, organized by different large companies, very complicated energy complexes arisen, gathering closely associated one to another systems. Their control is impossible without a quick and du decisions according high requirements for reliable and safety functioning, because possible failures in the energy system can have serious economic and social results. This requires a development and improvement of new methods in the organization and the control of huge energy systems.

The electro energetic system in Bulgaria is a complex corporate structure, including The National Electric Company and 52 sub-divisions in the country, electricity distributing companies, the Thermo-electrical Power Station "Maritza-East", The Nuclear Power Plant –Kozlodui. Each of its components is a complicated complex of different technical means, groups of people, gathered together within different departments and also include a combination of organizational and structural decisions (rules, service, etc.), organizational structure and technology of functioning [1].

A new tendency in the development of the power industry and the technical base worldwide is the replacement of the old equipment with new one. In the Electrical power stations and the substations, there are most often used systems for automation control, replacing the classic systems for distance control. The new quality high technology products ensure the safety and reliable operation of all technological processes.

The results from the investigations for the last 25 years show that nearly all accidents in the Nuclear power plants are because of human error but not because of technical defects and operation [2]. In many works for the investigation of the human factor (HF) there are mainly learnt the possible and potential reasons for human errors during the time preceding the accidents [3]. The HF is polysemantic and complex phenomenon dependent of different factors of the internal conditions and of the factors of external influences that lead in nowadays to different and not so actual evaluation of the reliability of the operator in the system "man-machine-environment". During the projecting of the control system there are taken into consideration the main characteristics of the human-operator (HO), such as the time for reaction of the man and the time for the execution of the situation and taking decision and the time for the necessary command to be passed. In this way, in a time of continuous complicating of the technological processes, of power growth, controlled by man, the psycho-emotional stress and the fast tiredness of the operator increased. Actual become the tasks associated with the development of optimal operating conditions for each separate case and also the training of the staff. It is seen from the above that the man is the most responsible by one side and the most unreliable part by the other in such complex man-machine systems (MMS).

II. Methods and Techniques for the Evaluation of the Human Reliability

The various processes in the MMS carry the potential possibilities for mistakes of the staff, mainly in cases when the time that the operator has to take a decision is limited. Also the probability this problem to increase into a negative plan, is often very small. The most of the actions of the staff are

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limited to the possibility to prevent the initial failure, preventing its growth into an emergency situation. To reach really objective evaluation, it is required analysis of the arisen because of human errors events. This is a hard and complicated process because of the existing limited concepts and lack of systematic description of the phenomenon.

The level of influence of the HF to the reliability of the system can be evaluated according the probability of appearance of mistakes during the process of functioning. The mistakes of the operator are usually connected with untrue interpretation of the incoming and analyzed by him data. It is considered that for the complex technical devices and complex computer tasks, the possibility for errors can reach 15% and for more ordinary one –the possibility for errors is from 1% to 5% [4, 5].

There is a big experience in the usage of methods for analysis of the risk in the human action and mainly in the nuclear power energy. The methods for preliminary estimation of the human errors are the most used for evaluation of the human reliability. The most famous and used in the practice theories are:

−THERT –Technique for Human Error Rate Prediction – Specifying the importance of the human errors in the technics;

−HCR – Human Cognitive Reliability – The reliability of the man related to his abilities. (according to Rasmussen);

−SLIM- Success Likelihood Index Method – Method of the indexes for possible success;

−DNE – Direct Numerical Estimation – Direct numerical evaluation-opinions (expert evaluation);

−MAPPS - Maintenance Personnel Performance Simulation – Method for modeling of the actions (errors) during the service of the technics.

The procedure for a system analysis of the human errors could have several steps according to the fact which of the mentioned methods are applied [6], [7].

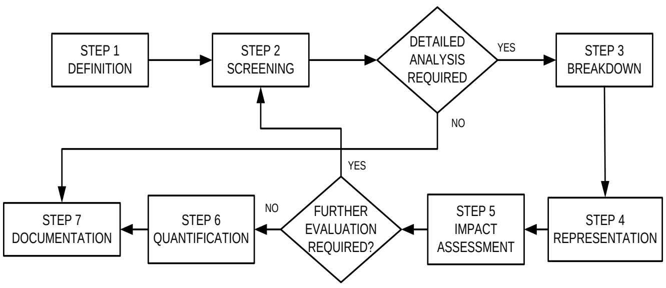

Fig. 1. System analysis of the errors

This procedure is known as SHARP –System Human Action Reliability Procedure and includes 6 steps and two stages: the first stage is executed by the system analytics, and the second –by specialist of the human factor:

Step 1: Defining of the human actions including activities for the accidents localization, repairs, etc. or all the actions that include errors of the staff that lead to failure in the operation of the whole system.

Step 2: Screening – selection of important events, errors that have a key importance for possibility of emergency situations.

Step 3: Separation- all the actions of the operator, requiring more careful analysis are separated which means that the action is divided into smaller elements/operations with the following characteristics:

- The ability to understand what should be done – separation by operations;
- Inability to define the system;
- Inability to execute the necessary actions;
- Expectation and system analysis of the safety;
- Necessity (possibility) to be worked-out an additional emergency plan, if there are found other errors of the operators;

Step 4: Representation –a full list with all errors and their analysis with similar actions;

Step 5: Specifying the interaction of the simple actions/ operations and the influence to the next stages;

Step 6: Quantification- specifying the quality values of the probabilities for errors;

Step 7: Documentation.

The model of the human actions is known as Model of human action – SPAR-H and is connected with the processing of the information by man and by the computerized procedures. The SPAR-H model include elements from the planning and also the probability of the operators to be able successfully to fulfill the actions that are identified with procedures which correspond to: usage of operational procedures; the "Ergonomics and Human-Machine Interface (HMI)" – forming and qualitative receiving of information from displays and controllers; “Complexity” of the tasks;

Analysis of the human reliability (Human reliability analysis – HRA). A detailed description of the most often used techniques, associated with the first and the second generation of the HRA is the Method for prediction of the frequency of the human error (Technique for human error rate prediction – THERP) and the Method for evaluation of the human error and its decreasing (Human error assessment and reduction technique – HEART). The examination gives an adequate view for the advantages and the disadvantages of each technique in order to evaluate the reliability of the human operations. The method gives a computer modeling and practically recognizes all factors and experimental data for analysis of the human errors. (there is a standard for their applying - NUREC/CR-1278).

For HRA– Human Cognitive Reliability (Reliability of the human according his abilities) uses the taxonomy of Rasmussen [8]. The correlation between the human reliability and the time is given by:

$$NRP = exp\left\{\frac{t/T_{1/2} - C_{y_i}}{C_{n_i}}\right\}^{B_i}, \qquad (1)$$

where, NRP is the probability for error (Non-Response Probability), t - available time, T_{av} - average time, C_{y_i} - retainment coefficient, connected with the mental process (specified according the Rasmussen factors), C_{n_i} - measuring factor , in a table there are defined the different factors such as practical skills of the operator, tiredness, stress, interface quality, etc., B_i - the available time for the mentioned factors to be reported.

As an example it can be used one of the base values of the human error, recognizing the correct understanding of the information from the control panel [6].

TABLE I
ERRORS IN THE DEVICE READINGS

	Presenting of the information	Probability for error (HEP)	Indefiniteness (EF)
1.	Analogue device	0,003	3
2.	Digital device (less than 4 digits)	0,001	3
3.	Self-writing device	0,0006	3
4.	Printing device with many parameters	0,5	5
5.	Diagram device	0,01	3
6.	Digital device with indicating lamps for digits showing	0,001	3
7.	Incertitude, that the device is safe when no indication for check.	0,1	5
8.	More than three symbols	0,01	3
9.	Simple arithmetical calculations	0,01	3
10	Finding by the mean of arithmetic calculations/ accounts of readings out of range	0,05	5

III. SPECIFYING OF THE INFLUENCE OF THE HUMAN FACTOR ON THE RELIABILITY OF THE CONTROL SYSTEMS

Each component of the MMS executes functions and set programs having specific quick-operation, accuracy and reliability. The evaluation of the reliability of the system “man-machine” can be done in different methods: analytic, experimental, imitation. On the project stage, there are mostly used the computing methods that are based on the statistic data for the reliability and the time necessary to the operator to execute the rated functions, the reliability of the technical devices, the influence of different environment factors, the coordination between the operator and the technics, etc. The reliability of the technical devices of the system gives the probability for faulty-free operation during the time necessary for a message to be sent P_T = 0,989 and the readiness coefficient is K_r = 0,958.

When evaluating he reliability of the operator work, there are examined three possible regimes: 1) Normal conditions (without stress); 2) During lack of time; 3) During information overload.

It is found that the reliability of the operator depends on the algorithm and the variety of the executed operations which is described by the equation [9]:

$$P_{ho} = exp\left(\sum_{j=1}^{r}\lambda_j T_j K_j\right) = exp\left(\sum_{j=1}^{r}(1-P_j)K_j\right), \quad (2)$$

where, P_j is the probability for execution of all operations of j-type without errors; λ_j - intensity of the errors of j-type; K_j - number of the executed operations of the j –type; r - number of the different types of operations $(j = 1,r)$

The readiness coefficient of the operator that is used for evaluation of the capacity of the system is defined by:

$$K_{ho} = 1 - T_0 / T, \quad (3)$$

where, T_0 is technical stop, the time when the operator is absent from the desk, when man does not process information; T - the full working time of the human operator.

If according the requirements for safety work of the operator it is necessary 10 min rest after 50 min work, then according to this indication the readiness coefficient of the operator will be: $K_{ho} = 0{,}833$. This testifies not only for “limited place” in the system but has influence to the organization of the working conditions and also to the system reliability [10]. According the calculations, the reliability of the operator is different when executing different types of operations: $P_{ho1} = 0{,}975$, $P_{ho2} = 0{,}960$, $P_{ho3} = 0{,}945$.

The errors of the operator are classified in three groups: misleading, disadvantages and negligence. They correspond to the cognitive stage in the different time intervals [7]:

Cognitive stage	**Type of mistake**
Training	Misleading
Knowing the Instructions	Insufficient knowledge
Execution	Negligence, mistakes

In this way, in order to specify the reliability of the system “man-machine”, it is necessary to know the characteristics of the faulty-free operation and of the time needed for execution of the different actions being part of the activities algorithm of the HO. The tendency for decreasing of the operator mistakes is to be according the level of his training and practice [11].

The data shows that during the execution of the different operations, the operator has a high reliability – from 0.95 to 0.999. It has to be taken into consideration that the evaluation is done during an experiment, when the operator has past special training, the working conditions are specified (comfortable), etc. In the real life everything is more complicated and so less reliable.

IV. CONCLUSION

The using of a complex method for analysis of the reliability of the human factor, gives the possibility to achieve more complex and true picture in contrast to the filled out probabilistic evaluation of the operator errors with determined indexes for his psycho-physiological state in real working conditions in the MMS. To increase the reliability of the operator in the field of the electric energy projects, during the operation of the MMS, it is necessary to cover the following most important principles:

- optimal separation of the control functions between the man and the machine;
- to choose automation devices adequate to the importance of the executed functions, connected with the safety;
- to create an optimal proportion between the activity of the operator and the systems supporting his activity;
- to create and use up-to-date interfaces “man-machine”.

The results from the complex approach for the analysis of the reliability of the operator activity can be used to specify the most rational variants of staffs when preparing the practical recommendations for the improvement of the means and ways to ensure effective functioning of the man in normal and accidental conditions on different energy projects.

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