

Technique for Assessing the Training Level of Operational Personnel at Electric Power Facilities Using Training Systems of the Digital Twin Type

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ABSTRACT

A technique for assessing the training level (competencies), which allows tracking the growth dynamics of the professional activity quality of the operator of an electric power facility in his/her preparation process using training systems of the Digital Twin type, has been developed. The temporal, accuracy, and reliability indicators of the operator have been used as an indicator of the level of the operating personnel training for error-free and safe operations. In each case, an indicator that most fully characterizes the quality of the candidate's performance of his/her functional duties is being selected.

A procedure for assessing a person's suitability for the required activity using diagnostic coefficients (points), which can be considered as weighting factors, has been proposed. The high reliability of the operating personnel selection at workplaces in assessing professional suitability has been achieved through the use of direct indicators of the quality of their activities. The proposed system will significantly reduce the examination time of professional suitability, increase the effectiveness of training, and determine the optimal number of trainings. Due to the availability of the database and the means for their automatic processing and visualization, it is possible to track the change in the level of development of professionally important qualities over time in the case of using this technique. The developed system allows simplifying the work of the user, who does not require special knowledge in psychology, mathematics, and programming.

Keywords: training, technique, virtual reality, competence, suitability

1. INTRODUCTION

Improving the professional preparedness of operating personnel for the error-free management of electric power facilities is carried out through professional selection, training, and education of knowledge, skills, as well as coaching when performing work of increased danger in order to prevent accidents [1]. In the psychological sense, the goal of training is the need to adapt people's behavior, and in the limit—to develop new ones or correct existing reflexes in case of emergency situations, which are prerequisites for incidents [2,3].

Professional selection is designed to determine the suitability of personnel for operational activities. The source material for assessing suitability are job analyses [4,5], which are a description of the necessary qualities and properties of a person for the implementation of operational activities in the form of physiological, mental, social-psychological, and other indicators. The list of these indicators for operating personnel includes:

- physical;

- psychosensory;
- psychomotor;
- intellectual sphere rating;
- assessment of temperament and character;
- social-psychological.

The quantitative value of the indicators is determined by the testing method. At the same time, the following requirements are imposed on the tests:

- validity, compliance with tasks;
- reliability as a measure of the result stability;

- differentiation, when with a single test only a certain quality is evaluated.

Professional suitability is established by the degree of correspondence of the psychophysiological qualities of a person to operational activities.

Training in the error-free and safe operation of the operating personnel requires knowledge on the general issues of labor protection of industrial and electrical safety and in the performance of the work provided for by official duties. It is usually carried out by means of programming teaching methods, including a functionally interconnected set of subsystems of educationalmethodical, informational, mathematical, and engineering-technical support and carrying out a question-answer-comment dialogue with a trained person. The training program consists of interconnected information modules with which the trainee learns knowledge. The training material is a hierarchy of data structures. For each level of the hierarchy, a location, a learning chain, and the prerequisites for achieving it have been defined.

In the formation of skills in operating personnel, special attention is paid to the formation of knowledge systems about equipment (design, modes, and controllability). In order to learn decision making methods, one uses algorithmic descriptions and situational games. The main purpose of training is the development of operational thinking, while the following points of operational activity are highlighted:

- surveillance and control;

- perception of information and assessment of the situation;

- fault diagnosis;

- selection of measures to eliminate it;

- troubleshooting.

When teaching decision-making, training information is given as a set of situations organized into a tree-like data structure, the root of which is the initial function given to the trainee as a condition of the problem, and the vertices are the possible final situations. The active use of queries in the decision-making process provides additional information. Depending on it, a set of possible situations—a trainee's action model—is being created.

At the present stage of digital technology development, virtual reality has become widespread in educational technologies and implemented in various industries [6-11]. However, the methodological issues of assessing the

effectiveness of training using such systems are not fully considered.

For the formation of operating personnel's skills of safe activities, a training system of virtual reality can be used, which includes as follows:

• Digital Twin of a productive facility

• a set of emergency development scenarios;

• a system for evaluating the correctness, sequence of actions, and time of their execution.

The virtual reality training system represents the unity of the object simulation systems and the organization of the educational process with quality control of the trainee.

The virtual reality training system should simulate the operation of an object both in normal modes and in modes with a malfunction of the basic equipment. Simulation of processes in the object reproduces emergency and other modes with a malfunction of equipment in real time. The list of malfunctions is compiled on the basis of the analysis of the operating experience of the object—the prototype. In terms of the amount of incoming information, the trainee should make decisions and take actions aimed at eliminating technological disturbances. Errors in the actions of the operating personnel most often occur, when a person skips some actions, performs incorrect or untimely actions, which he/she is obliged to fulfill to exclude technological disturbances.

The algorithm for illustrating the behavior of people in emergency situations and in the absence of ready-made control solutions for them can be represented by the logic diagram shown in Fig. 1.



Figure 1 Algorithm of human behavior in a non-standard situation





Figure 2 The scheme of the formation of dangerous or erroneous human actions in the process of activity

2. RESULTS OF EXPERIMENTAL RESEARCH

As an indicator of the level of the operating personnel preparation for error-free and safe operation, one can use temporary, accurate, and reliable indicators of the operator.

The dependence of the quality of the operator' training (competency level) and the correct response to the amount of incoming information is an exponential function:

$$Q = Q_{max}(1 - W_0 e^{-I/I_0})$$
(1)

where Q_{max} – level of training (quality of

activity) of the operator with the least possible disorder of activity W_{o} ;

 W_0 – initial disorder of the operator's activities, depending on the response to incoming information and the sequence of actions performed;

 I_0 – constant characterizing the preparedness of the operator to receive, process, and use information.

It is assumed that the amount of control information processed by the operator is proportional to the time spent on its preparation, i.e., $I = \alpha t$, where α is some function that characterizes the training system.

Irregularity of the operator's activity can be defined as a measure of deviation of his/her state from some optimal one, ensuring the highest possible quality of work

$$W = W_0 e^{-\frac{1}{I_0}}$$
(2)

Then the expression (1) takes the form

$$Q(t) = Q_{max} \left(1 - W_0 e^{\frac{t}{t_0}}\right)$$
 (3)

where $W_0 = (Q_{max} - Q_0)/Q_{max}$: t_0 – factor characterizing the operator's ability to learn (in units of time); Q_0 – initial indicator value Q(t).

The expression (3) allows to quite clearly present the growth dynamics of the operator's quality in the process of his/her training.

If we consider that the time spent on training is proportional to the number of training sessions, then we can write

$$Q(n) = Q_{\max} \left(1 - W_0 e^{\frac{n}{n_0}}\right)$$
(4)
where n – number of workouts; n₀ – base number of



Figure 3 – Dependence of the operator's training quality (competency level) Q of the trainee on the amount of information used I.



Dependencies (1), (3), (4) show the dynamics of changes in the level of training, which increases with the accumulation of experience, depending on the number of trainings, time to complete the task, sequence, correctness of decisions made, etc.

The procedure for assessing a person's suitability for the required activity consists in calculating diagnostic coefficients (points), which can be considered as weighting factors of indicators.

The diagnostic factor of the i^{th} indicator of the j^{th} gradation is calculated by the formula

$$D^{i}_{j} = lg \frac{A^{i}_{j} N_{jb}}{\dot{b}_{j} N_{j}}$$
(5)

where A^{i}_{j} and B^{i}_{j} – the frequency of occurrence of the *i*th indicator of the *j*th gradation for the base A and B of the subject, respectively;

 $N^{i}{}_{A}$ и $N^{i}{}_{b}$ – the total number of persons in each of the groups whose data were used to construct the distributions for the *i*th indicator.

A similar calculation is carried out for all gradations of the selected informative indicators and a table of values is compiled depending on them.

In order to determine the threshold of suitability (unsuitability), it is necessary to preliminarily set admissible error values of the 1st and 2nd kind, which numerically determine the probabilities of selecting an "unsuitable" candidate (a) and dropping out the "suitable" (β). In this case:

 $\Pi_{\scriptscriptstyle A}$ – threshold of suitability

$$\Pi_{A} = \ln(1-\beta)/\alpha, \tag{6}$$

 $\Pi_{\rm E}$ – threshold of unsuitability

$$\Pi_{\mathbf{b}} = \ln \beta \, (1 - a), \tag{7}$$

When establishing acceptable values, α and β , the possible consequences of the participation of unsuitable persons in the work should be taken into account. If a small number of individuals are required to be selected from the surveyed contingent for further work, then we can accept $\alpha=\beta=0.1$ or 0.05.

If it turns out that admitting an "unsuitable" candidate to operational activities will do more harm than dropping out a capable individual, choose different values for a and β (i.e., $a \neq \beta$).

The criteria obtained, together with a description of the organizational and methodological forms of conducting psychophysiological selection, are given in special instructions. In general terms, the methodology for determining the professional suitability is as follows: for each person, undergoing psychophysiological selection, quantitative values of pre-established indicators are found. In accordance with the values of these indicators, the value of the diagnostic factor is determined from the experimentally developed table, after which the

algebraic sum of these Π factors is calculated for each person.

If $\Pi > \Pi_A$, a decision is made on the suitability of the candidate for operational activities; if $\Pi < \Pi_B$, then the candidate is unsuitable; if $\Pi_B < \Pi < \Pi_A$, then the available information is not enough to solve the issue of suitability with the required probability (i.e., for the selected values of α and β).

An assessment of professional suitability, based on the theory of pattern recognition, was used additionally in the absence of a clear opinion and suitability of test results B.

Psychophysiological abilities of a person are evaluated by a set of values of their indicators q_1, q_2, \ldots, q_n , for these indicators, the logarithm of the likelihood ratio is calculated. Depending on its size, a person can be assigned either suitable for activity or not.

$$L(q_1, q_2, ..., q_n) = \ln \frac{fA(q_1, q_2, ..., q_n)}{fB(q_1, q_2, ..., q_n)}$$
(8)

In the expression (8), $f_A(q_1, q_2,..., q_n) \bowtie f_B(q_1,q_2,..., q_n)$ represent the conditional distribution densities of the set of test indices $q_1,q_2,..., q_n$ in each group. If each of the tests has one indicator and the indicators are independent, then

$$L(q_1, q_2, \dots, q_n) = \sum_{i=1}^n Li \ (q_i) = \sum_{i=1}^n ln \frac{f(i)A \ (q_i)}{f(i)b \ (qi)}$$
(9),

where $L(q_1,q_2,...,q_n)$ – algebraic sum of points received by the candidate according to the results of his/her work with tests; $f_A^{(i)}(q_i)$, $f_B^{(i)}(q_i)$ – distribution density of the *i*th indicator.

By analogy with the first type of criteria, the logarithm of the relation $f_A^{(i)}(q_i)$, $f_B^{(i)}(q_i)$ is called the diagnostic factor or score of the *i*th indicator.

A person is considered to be suitable for operational activities, if

$$L \ge L_0. \tag{10}$$

A person is considered to be unsuitable for operational activities, if

$$L < L_0.$$
 (11)

where L_0 – the set value of the suitability of a person for operational activities obtained experimentally.



3. RESULTS AND DISCUSSION

Criteria for predicting the professional capabilities of individuals based on the results of personal operational activities directly at workplaces in each case require serious scientific justification for the appropriateness of their use. Such criteria characterizing the quality of activity may be the probability, time or accuracy of the performance of individual operations, or their aggregates.

The high reliability of the selection of the operating personnel at workplaces in assessing professional suitability is achieved through the use of direct indicators of the quality of their activities. However, obtaining sufficiently reliable results is associated with a rather lengthy examination, which is not always possible.

In most cases, professionally significant qualities of working operating personnel are raised in the application of virtual reality training systems.

4. CONCLUSION

The developed technique for assessing the level of training (competencies) allows tracking the growth dynamics of the professional activity quality of the operator in the process of training using virtual reality training systems.

Application of the developed automated system will significantly reduce the examination time to increase the effectiveness of training and to determine the optimal number of workouts. Due to the availability of the database and the means of their automatic processing and visualization, it is possible to track the change in the level of development of professionally important qualities over time in the case of using the appropriate technique. The developed system allows simplifying the work of the user, who does not require special knowledge in psychology, mathematics, and programming.

ACKNOWLEDGMENT

The reported study was funded by RFBR, project number 19-38-90266

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