Development of the system for preparing, maintaining and qualification improving of operational personnel of energy organizations

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Abstract. This article discusses the structure of the system for preparing, maintaining and qualification improving of operational personnel (SPM and QI) of energy organizations and the main results of the work for its development with the participation of the author in the National Research University “MPEI” and energy organizations, in terms of legal support, organizational support, technical and mathematical support, software and methodological support for this system.

1. Introduction
According to the requirements of regulatory documents [1,2], the owners of electric power facilities organize a system for preparing, maintaining and qualification improving of operational personnel (SPM and QI), conduct ongoing work (work with personnel), which is aimed at ensuring the readiness of operational personnel to perform professional functions, including conducting mandatory forms of work with the specified personnel - preparing for a new position, knowledge testing and emergency training, and qualification maintaining.
In order to develop the structure and content of SPM and QI, the following work results were developed and implemented in energy organizations.

2. Regarding the legal support of SPM and QI
2.1 Based on the analysis of the main trends in simulator building and computerization of the training of personnel of power units [3], the Standards for the availability of software for preparing personnel in the energy sector were developed (RD 153.34.0-12.305-99, hereinafter referred to as the shelf life standards), approved by RAO EES of Russia on 02.06.1999, and certification of software preparing personnel for compliance with the specified standards [4].
Shelf life standards include:

- functional shelf lifes of software for preparing (hereinafter - SP);
- software and technical shelf life;
- the shelf life of the accompanying documentation.
It is divided into shelf life standards:
- simulators;
automated educational courses and automated learning systems;
educational training complexes.

So, the conclusion of the implementation of the rules of shelf life of the simulator should include the results of examinations of performance:

2.1.1. Functional shelf lifes in terms of meeting the requirements for:

• models of the control object:
  - completeness of modeling of technological equipment and subsystems of automated control systems (hereinafter - ACS), controlled parameters of control objects;
  - completeness of reproduction of normal operation modes, as well as accidents and failures in equipment work;
  - the accuracy of modeling the control object and subsystems of the automatic control system in normal exploitation, in the presence of accidents and failures;
  - preservation of the real scale of simulation time;
  - fixation of going beyond the modeling area.

• workplaces of trainees:
  - the sufficiency of the used videograms (mnemonic diagrams with the values of controlled parameters, control devices and graphs of their changes in time, computer images of remotes and panels of real workplaces of the trainees) to display the state of the control object and subsystems of the ACS;

• workplace of the instructor:
  - preparation and conduct of the training (the presence and sufficiency of a set of different initial states of the control object, the possibility of preliminary (prior to the start of the training) programming of the input of individual accidents and failures in the operation of equipment and means of ACS, the possibility of stopping and changing the scale of simulation time);
  - analysis of the training results (fixing the initial state, the moment of the beginning of the action and the emergency inputs used, as well as the time spent on the training, the actions of the trainees, triggering of technological protections and locks, time schedules of the most important controlled parameters and the position of the control devices).

2.1.2. Software and technical shelf life:

• general rules:
  - work without accidents, hangs and premature terminations by failure;
  - compliance with SP compatibility requirements on all computers of the declared type;
  - the absence of undocumented and unauthorized by the user actions;
  - fulfillment of requirements for launching a SP (use of standard tools, minimal presetting);
  - release of resources after completion of the SP;
  - the ability to work in a local area network (recommended).

• requirements for SPs running under Windows or UNIX:
  - compliance with the rules for designing the working field of the program and the principles of building the user interface;
  - the presence of a single software launch group for the memory bandwidth, consisting of several start-up modules.

2.1.3. Shelf life of accompanying documentation:

• availability and completeness of manuals:
- instructor;
- trainee;
- on exploitation and work with application software;
- on work with tool software;
- for testing and verifying the simulator performance.

For each of these positions - according to paragraph 2.1.1 (including the fulfillment of the norms of validity of modeling a control object, workplaces of trainees and instructors) 2.1.2 and 2.1.3 evaluate the result of the implementation.

The general conclusion on the fulfillment of the fitness standards for the simulator should contain a conclusion on the possibility of its use for certain categories of personnel (a detailed list of specialties for which this simulator can be used is given) and specific types of preparing (initial preparation, preparing for an operational position, advanced preparing within the framework of previous position, retraining for a new post, emergency training, competitions and contests of professional skills) [4]

2.2 In accordance with the requirements of Clause 2, Article 21 of the Law on «Electric Power Industry» No. 35-FZ dated March 26, 2003, the Unified Attestation Requirements and the «Certification Procedure for Persons Carrying Out Professional Activities Related to Operational Dispatch Management» were prepared and approved by the Ministry of Industry and Energy of Russia [5] in electric power industry.

The Rostekhnadzor preparing and conducting state certification in the EES of Russia of the system of state certification of persons professionally performing operational dispatch control in the electric power industry, including the preparation and submission to Rostekhnadzor of information about the technological conditions of dispatch centers, the organization of pre-certification training and technical support for the certification procedure using software complex "Expert Dispatcher". This ensured the timely passage in January-February 2007 of the first state certification of 725 dispatchers and 233 employees of OAO «SO-CDU EES» from among the administrative and technical personnel whose responsibilities include the management and organization of the activity of dispatchers (chief dispatchers and their deputies, Heads of operational dispatch services and their deputies) while maintaining the continuity and reliability of the operational dispatch control of the EES of Russia [6].

3. In terms of organizational support of SPM and QI

Work with personnel is one of the main areas of activity of electric power organizations [2] for which, the latter stand out (create) subdivisions, one of the most important tasks of which is the organization and control of work with personnel.

As a rule, these are subdivisions of a technical audit (internal technical inspection) of organizations that build this activity on the basis of development, coordination with Rostekhnadzor authorities and approval of the personnel work procedure, which was implemented when creating the technical audit system at OAO «SO-CDU EES».[7].

To organize the functioning of SPM and QI and ensure personnel readiness, the owners of electric power facilities should create training centers (points) with educational classes equipped with learning and simulator training facilities, equipped with instructor personnel and able to attract highly qualified specialists to teaching [2].

The formation of requirements for the composition, equipment and automation of the design of simulator points for power plants was further developed during the development and subsequent implementation of a systematic project for the creation of a system of centers and training centers for personnel at OAO «SO-CDU EES» resulting in all dispatch centers of OAO «SO-CDU EES» were created and equipped with training facilities certified centers and points for training personnel. The training center simulator training hall of the center for preparing the personnel of the Joint Dispatch Center of the North-West is shown in Fig. 1 [7].
4. In terms of mathematical, software and technical support for SPM and QI

4.1 To create simulators for power units of nuclear power plants with VVER reactors, a mathematical description of the dynamic processes in the pressure compensator (PC) has been developed, experimental studies of which indicate the presence of equilibrium during one transition mode (when the water and steam temperatures correspond to the saturation state at the current pressure value in the PC) and nonequilibrium processes in PC [8].

When describing the processes in the PC, it was proposed to use the following assumptions:
- water in the PC volume can be underheated and saturated, heating of saturated water almost instantly (during the calculation step) leads to steam generation;
- steam in the PC volume can be overheated and saturated (under a water mirror - only saturated), cooling of saturated steam almost instantly leads to condensation of part of the steam;
- condensation of steam in unheated water and heating of water injected into steam to a state of saturation also occur almost instantly;
- the pressure at all points of the pressure vessel is the same;
- volumes into which PC is divided are considered as concentrated capacities.

The design scheme of PC, presented in Fig. 2, includes two water volumes, the main steam volume and two volumes of steam located in two water volumes. A small volume with a constant mass of water was selected in the lower part of the PC to account for poor mixing of the water coming from the hot string with the main water of the PC.

Figure 1. Training center simulator training hall of United Northwest dispatch center
A special method for calculating the dynamics of PC has been developed, which instead of having to use eight different descriptions of the processes in the PC for two volumes of water and the main volume of steam, only eight cases of calculating the additional generation of steam in two volumes of water are taken into account (if the enthalpy in them is greater than the saturation enthalpy in the next calculation step) and additional condensation in the main volume of the vapor (if the vapor enthalpy in it is less than the saturation enthalpy at the next calculation step).

The results of calculating the pressure dynamics in the PC and comparing it with experimental data for a power unit with a VVER-440 reactor under disturbance by the movement of the working group of the reactor rods up 80 centimeters are shown in Fig. 3 [8]. They say that for a correct description of the dynamics of PC, taking into account both poor mixing of water coming from the primary circuit with the main water of the PC and the superheating of steam in this case (model 1) is essential. Failure to take these factors into account leads to noticeable deviations of the calculated pressure values in the PC from the experimental values (model 2).
Figure 3. The results of calculating the pressure dynamics in the pressure compensator and comparing it with experimental data for a power unit with a VVER-440 reactor when moving the working group of reactor rods up 80 centimeters.

4.2 In the course of work on the creation of software and hardware for SPM and QI, the following were created:

- a small simulator for preparing operators of nuclear power plants with VVER [9];
- a PC-based interactive simulator for a nuclear power unit with a VVER-1000 reactor [10];
- an automated learning system [11], and subsequently - a set of computer tools for preparing personnel of thermal automation and measurement workshops (hereinafter - TAMW, in Russian - CTAI) of power plants.

So, the basis of the complex for the preparing of the personnel of the TAMW is formed by the educational training modules, each of which is a full-fledged automated educational course on control, automatic regulation or technological protection, accompanied by specialized computer simulators. A typical educational training module consists of five sections. The “Theory” section provides the basics of the functioning of the automated control systems under consideration, the “Design (schemes)” section reveals its design (schemes) features. The section “Installation and operation” covers all the main types of personnel actions related to the current operation of the equipment (preparation and commissioning, typical operation operations, decommissioning). The “Faults” section provides information on the main types of failures and malfunctions of the equipment under study, diagnostics, and methods for their recognition. In the "Training" section, the student is given the opportunity to work out installation and operational operations, to acquire practical skills in recognizing typical failures and malfunctions.

The content of the educational training module is designed for educating in programs of various difficulty levels (TAMW shift supervisor, engineer on duty, electrician on duty). The educational material is divided into elements of educational information, each of which consists of two parts: training and control. The student has the opportunity to work in the following modes:

- educating - only theoretical material is presented without control questions with the ability to move across the text in any direction;
- educating and control (programmed educating) - theoretical material is interspersed with control questions. If the answer is incorrect, the program returns the question with the simultaneous fixation of the erroneous answer, the results of the responses are recorded in the protocol;
The complex of computer tools for preparing personnel of the TAMW of power plants has been introduced into the work of the training point of the Tverskaya (Kalinin) nuclear power plant, as well as at a number of thermal power plants. Certified for compliance with the standards of suitability as an educational training complex for use in thermal energy [4].

5. In terms of methodological support for SPM and QI

5.1 The methodology for checking the accuracy of simulator models has been developed. Based on the results of experimental studies of the distinction by a human operator of the deviations obtained from the model of transients from the reference ones, including changing the gain and time scale, the type of transient, the method of displaying information and the number of simultaneously monitored parameters, as well as an expert assessment of the admissibility of these deviations, when it is still possible use of the model as a part of the simulator (with the involvement of leading instructors of the training centers) a technique for checking the accuracy of simulator models has been developed. To determine the admissible dynamic error of the simulator, it is necessary to set the required probability of a positive vote by experts, then, according to the graphs of the relative (with respect to the probability of identification of the standard) probability of the admissibility of using the developed model as part of the simulator \( P_\text{rel.un} / (P_\text{rel.un})' \), the admissible value of the deviation measure of the model \( V_{\text{rel.un.}} \) (rel. un. – relative units) is determined, which using the graph of the relative degree of adequacy of the \( P_\lambda / (P_\lambda)' \) model, it is possible to determine the corresponding value of the degree of adequacy of the model acceptable for the conditions under consideration (Fig. 4). So, with a relative probability of a positive vote of experts at 85%, a spread of standards of 7.5%, and a number of simultaneously monitored parameters \( n \) of at least 7, the acceptable values of the relative degree of adequacy of the model will be: for the graphical form of presentation of information - 89%, for the digital form - 77 %, for devices with a horizontal scale - 78%, with a dial - 76% [12, 13].

Figure 4. Dependence of the relative probabilities of a positive expert vote and the degree of simulator model adequacy on the deviation measure for various ways of presenting information

In relation to the previously considered models of PC dynamics when using the digital form of information presentation, the relative degree of adequacy of models 1 and 2 (see Fig. 3) will be, respectively [12]:

- control - educating material is not displayed, only control questions are presented with the subsequent recording of the control results in the protocol.
- with three simultaneously controlled parameters: 97.7% and 43.5%;
- with seven or more simultaneously controlled parameters: 98.8% and 71%.

These results indicate the need to use a much more accurate model 1 in specialized simulators (modes) to develop PC management skills and a small number of simultaneously controlled parameters. If the number of simultaneously monitored parameters is increased to 7 or more, a simpler model 2 can be used (corresponds to 80% of the relative probability of a positive vote by experts about the possibility of using it as part of the simulator under these conditions).

When assessing the static accuracy of the simulator model, the main attention is paid to the stationary points of the transient process (beginning, end, extrema), the permissible modeling error in which is determined by the spread of the controlled values of the analyzed parameters and the error of reading information by the operator - up to 2% and 10% of the nominal critical and auxiliary values parameters, respectively (with the exception of individual parameters, the monitoring of which uses more accurate measuring instruments, for example, the number of revolutions of the turbogenerator rotor). In addition, the errors in determining the material and energy balances in the initial and final state of the simulation object should also be estimated based on a set of controlled parameters used as a standard for the analyzed unit operation mode.

The developed technique for checking the static and dynamic accuracy of simulator models allows us to formalize the procedure for such verification and to carry out it without the presence of experts at any stage of simulator model development, starting from the stage of creating individual elements.

5.2 Instructive and methodological materials have been prepared on the use of the developed simulators and computer-based training tools [12], the use of the educational training complex for the preparing of personnel of the TAMW power plants in professional skill competitions [14].

In nowadays:
- the shelf life standards of the software for personnel preparing on October 29, 2013 are included in the non-profit partnership “Interregional Association of Organizations Carrying out Activities in the Field of Continuing Professional Education in the Energy Sector” in the voluntary certification system as a partnership standard (STP 04);
- pre-certification preparing and certification of persons engaged in professional activities related to operational dispatch control in the electric power industry is carried out in accordance with [5], 8 training centers and 49 training points for personnel are functioning in the system operator of EES of Russia;
- actualization of the content and development of new training tasks allowed the continued use of the educational training complex of computer tools for preparing personnel of the TAMW power plants in professional skill competitions at various levels, including the All-Russian ones.

6. References

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