Simulating Systems for Advanced Training and Professional Development of Energy Specialists in Power Sector

Viktor Gurieiev[1[0000-0002-8496-3626]], Yulii Kutsan[1[0000-0002-0361-3190]],
Anna Iatsyshyn[2,3[0000-0001-8011-5956]], Andrii Iatsyshyn[1,2,3[0000-0001-5508-7017]],
Valeriia Kovach[3,4,5[0000-0002-1014-8979]], Evgen Lysenko[1[0000-0001-7833-5116]],
Volodymyr Artemchuk[1,3[0000-0001-8819-4564]] and Oleksandr Popov[1,3,5[0000-0002-5065-3822]]

[1] G.E. Pukhov Institute for Modelling in Energy Engineering of NAS of Ukraine,
15, General Naumova Str., Kyiv, 03164, Ukraine
[2] Institute of Information Technologies and Learning Tools of the NAES of Ukraine,
9, M. Berlynskoho Str., Kyiv, 04060, Ukraine
[3] State Institution "The Institute of Environmental Geochemistry of the NAS of Ukraine",
34a, Palladin Ave., Kyiv, 03680, Ukraine
[4] National Aviation University, 1, Cosmonaut Komarov Ave., Kyiv, 03058, Ukraine
[5] Interregional Academy of Personnel Management, 2, Frometivska Str., Kyiv, 03039, Ukraine

viktor.gurieiev@ipme.com.ua, anna13.00.10@gmail.com

Abstract. The crisis of the system of professional development and personnel training in the energy sector exists not only in Ukraine but also all over the world. The article describes the concept of development and functioning of the industry system of personnel training in the energy sector of Ukraine. The importance of using modern web-oriented technologies to improve the skills of operational and dispatching personnel in the energy sector of Ukraine is substantiated. The methods of distributed power system operating modes modelling are presented. Development and software tools for the construction of distributed simulating systems and particular features of cloud technologies application for the creation of a virtual training centers network in the energy sector, as well as the ways to automate the process of simulating scenarios development are described. The experience of introducing remote training courses for energy specialists and remote web-based training simulators based on a comprehensive model of the energy system of Ukraine is presented. An important practical aspect of the research is the application of software and data support for the development of personnel key competencies in the energy sector for rapid recognition of accidents and, if necessary, accident management. This will allow them to acquire knowledge and practical skills to solve the problems of analysis, modelling, forecasting, and monitoring data visualization of large power systems operating modes.

Keywords: simulating systems, simulators, professional development, operational and dispatching personnel, energy specialists, energy sector.

1 Introduction

In the developed Energy Strategy of Ukraine till 2035, one of the most important goals is integration into the EU energy space and strengthening of global ties [11]. The United Energy System (UES) of Ukraine integrates a large number of technological equipment distributed throughout the country intended for the generation, storage, transportation, distribution and use of energy. Highly qualified personnel must manage the operational management of power equipment. Insufficient staff qualification and lack of readiness to quickly eliminate emergency situations lead to major accidents and enormous material costs to restore energy supply [3].

It shall be noted that a considerable number of problems have accumulated in the Ukrainian energy sector now, and the main one is the lack of a single policy in the field of personnel education and training. The structure of the energy management system of Ukraine does not imply an organization, which could be responsible for the development of standard curricula and academic programmes for professional training of personnel, scientific and methodological and information support of the personnel training system, introduction of new technologies and best practices, achievements in science and technology. None of the organizations basically solves the tasks of providing the necessary level of qualification of the energy sector personnel, improving its efficiency and quality, quality control of general and special training of the personnel or testing personnel knowledge. At the same time, personnel development is one of the key tasks of the power industry leaders. The proper solution to this problem will increase productivity and ensure reliable, safe and accident-free equipment operation.

At present, the training and development of energy professionals are aimed at:

1. professional development for the formation of key competences in order to recognize the conditions of cyber threats, emergencies, and methods of their rapid elimination, which involves the application of theoretical and practical methods related to the processes of generation and distribution of energy, characterized by interdisciplinarity [5];
2. development of the ability to use information and communication technologies, introduce them to the latest developments, systems, software tools helping simulate and forecast the conditions of a complete power failure and develop the skills to use these tools in further professional activity;
3. training highly qualified and professional “industry elite” dispatchers capable of solving scientific problems and issues regarding the optimization of large power systems operating modes, as well as solving practical tasks of the digital transformation of the industry [4, 5].

The training and professional development system for energy industry personnel should be automated and remote to the extent possible, involving the use of training systems, cloud technologies and augmented reality [7, 8], to make it interesting and effective.

2 Literature Analysis and Problem Statement

Various causes of emergencies at energy objects are discussed scientists V. Artemchuk [20], B. Choi [10], K. Jeong [10], A. Iatsyshyn [20], V. Kovach [20], J. Moon [10], F. Paraschiv [27], O. Popov [20], M. Spada [27], et al. Design of mathematical and software tools for assessing the impact of fuel and energy enterprises on the economic component of the country and the environment [21, 22]; theoretical methods and practical tools for mathematical and computer simulation in the energy sector researchers I. Blinov [2, 14], O. Kyrylenko [14], A. Zaporozhets [33, 34], et al. The problems of creation and diagnostics of power equipment and simulating systems for the energy industry are described in [33, 34]. The problems of distance and blended learning of specialists in different fields have been the subject of study by scientists: V. Kukharenko [12], S. Lytvynova, [24, 28], S. Semerikov [17, 18], O. Spirin [28], T. Vakaliuk [16], et al. The features of power engineering and ecology specialists training and professional development in the field of energy and ecology have been investigated researchers E. Avetisyan [3], V. Gurieiev [3, 4, 5, 30], A. Iatsyshyn [13], V. Khoziyev [19], Y. Kutsan [13], V. Okhotin [19], V. Samoylov [26], O. Sanginova [3, 4, 5], et al. However, it is important to analyze and summarize the existing experience of using training systems to enhance the skills and training of energy professionals.

3 The Aim and Objectives of the Study

The purpose is to analyze and to summarize the experience of using simulating systems to improve the qualification and professional training of energy specialists, describe further directions of improving the system of professional development of personnel in the energy sector of Ukraine.

Tasks of the research:

1. To generalize the experience of applying simulating systems and substantiate the conceptual foundations of training and professional development system for specialists in the field of energy of Ukraine.
2. To identify the features of simulating systems development for energy.
3. To consider the principles of the development of objects and scenarios of simulating systems and identify the main directions of modernization of the system of training and professional development of specialists in the energy sector.

4 Research Results

4.1 Conceptual Foundations of Developing a Training and Professional Development System for Energy Sector Specialists in Ukraine

In the strategy of reforming the State Enterprise National Energy Company "Ukrenergo" (SE NEC "Ukrenergo") [29], professional staff development is one of the important elements of the strategy. It is planned to develop a corporate automated knowledge and test database within the framework of the long-term personnel professional development system implementation. Its main reason is to develop training programs within the context of training centres, to implement game training and assessment methods during 2019-2020, and to refocus training on competency development and innovations, as well as practical improvement of technical skills by 2026.

It is important to plan state policy in the field of personnel training and professional development for a long period, to identify the sources of funding people responsible for providing all preparatory work, including the implementation coordination and monitoring.

The scientists of G.E. Pukhov Institute for Modelling in Energy Engineering of NAS of Ukraine, which have significant achievements in the energy sector, propose to develop a system of personnel professional development in the energy sector by integrating all educational institutions of the country carrying out energy research and providing energy-related education services into a new scientific and educational cluster in collaboration with other higher educational establishments and institutions [3].

The purpose of the proposed concept of the energy professionals training system is to organize a blended classroom and remote form of training and simulation applying information and communication technologies for the mandatory sustainable formation, verification, and control of key competences of the operational and dispatching staff of the energy sector of Ukraine. The competences to be mastered or developed by the personnel of the energy industry ensure the continuous reliable operation of the equipment and modes of operation of the UES and electric energy associations (EEA). They relate to the processes of dispatching control, organization of safe conditions of electrical equipment operation, recognition of accident causal factors and scenario analysis, formation and development of skills of quick emergencies elimination, techniques (rules) of regular and emergency switches at substations, in electric networks, etc. [3].

An analysis of the international experience of personnel training in the energy industry confirmed that the outlined competencies of staff can be formed solely with the help of full-featured simulators.

Currently, in Ukraine and in the EU, there are a large number of unresolved issues related to continuous education and professional development of UES and EEA personnel. Therefore, this problem requires further research and involvement of the world's best educational standards and learning technology.

In Ukraine, the issues of professional training of employees are regulated by the Laws and other guiding documents [6, 15], the obligations to maintain the proper level of staff competence are imposed on the management (employers' organization) of energy enterprises of all levels of the existing management hierarchy. However, practice shows that the capabilities of state-owned enterprise heads are now very limited by the amount of public funding. The existing system of professional development of energy personnel in Ukraine is based on the outdated intramural form of study as a part of compulsory training, once every three years 2-3 weeks long. In Ukraine, the most important component of operational and dispatching personnel development, which is a simulating system, is missing. This fact very much hinders the formation and development of the required staff qualification, for example, within the context of recognizing the conditions of occurrence and elimination of various accidents [3].

To date, the cost of business trips (travel, food and lodging) far exceeds the cost of training itself. These conditions of professional development make it difficult to form full-fledged homogeneous groups, adequate content of the educational and methodological base, and the use of effective methods of training and simulating system. There are also problems with the recruitment and training of instructional staff involved in professional development.

At present, an important trend for the social development of the world countries is the use of various information and communication technologies, in particular, virtual simulators in all fields of production activity, especially in the energy industry. In the energy sector of different countries European Network of Transmission System Operators for Electricity has created and successfully used a large number of electronic training systems and simulators. However, the major drawbacks of these systems are their narrow scope. Therefore, it is important to design and upgrade existing simulating systems, in particular, to develop their browser-based and mobile versions to use within the context of distance learning.

The implementation of the proposed Concept will be effective if we summarize the accumulated experience with the energy experience of the European Union countries and determine the membership of the main implementing organizations. The next step is to propose and agree with the SE NEC "Ukrenergo" a pilot project of an electronic simulating system by 2022, as well as to envisage the possibility of involving the European experts to the proposed concept of implementation.

4.2 Aspects of the Development of Simulating Systems for Energy Specialists Training

We agree with [25], that simulating systems for energy specialists training should be aimed at developing competencies and should be based on modern training technologies, including distance learning. An important component of the quality of staff training is the content of training programs, methodological support and a system of assessment of the quality of employee training.

The system of quality assessment of personnel training in the energy sector must necessarily include tools for measuring the level of knowledge, the ability to solve real, non-standard tasks, complicated by conflicting requirements, often in the context of incomplete or insufficient information, the ability of workers to synthesize and analyze situations arising in their professional activity.

In order to support high-level thinking and create the conditions for independent learning, simulating systems should provide staff with the ability to control employees' intrinsic motivation to learn, as well as the potential to create complex tasks that allow new information to be linked to the old one, find a place to personalize the experience, get acquainted with the experience of fellow professionals. Thus, these principles of organization of simulating systems training base guarantee personnel individual professional development, contribute to the acquisition of new knowledge and skills, affect the social improvement of staff, including the professional level and confidence in their knowledge [3].

Nowadays, blended and distance learning, which is a modern trend and has a significant impact on cost savings, should be used to enhance the skills of energy professionals. Blended learning combines classroom and e-learning technologies and is based on the application of information and communication technologies. The advantage of blended learning is that specialists can combine professional activities and learn at their own pace without wasting time.

An important element of distance learning is a distance-learning course. A distance-learning course should be designed to motivate students to work independently and actively interact with the system, to monitor the process and progress of learning. Therefore, the development of distance training courses for simulating systems applied by energy specialists requires high-quality teamwork of specialists - methodologists and experts in the energy sector - as well as the comprehensive application of didactic, technical and electronic training and control tools [19, 30].

The authors of this article and specialists from Scientific Production Enterprise LLC Infotech [9] have already developed a number of distance learning courses for distance learning and training of operational and dispatching staff in cooperation with the SE NEC “Ukrenergo”, PJSC Kyivoblenergo and Center for the professional development of managers and specialists of the Ministry of Energy and Coal Mining of Igor Sikorsky Kyiv Polytechnic Institute: “Simulation System and Emergency Response Drill Using Full-Featured Web Mode Simulator”, “Methods of On-line (Real-Time) Process Optimization of Operating Modes of the Unified Electric Power System of Ukraine”, “Automated Preparation of Switch Cards at the Substations of the SE NEC “Ukrenergo”, “Creating Emergency Response Drill Using HSC RS ++”, “Designer-Editor of a Full-Featured Web Mode Simulator to Create Routine and Emergency Response Drill”. These distance learning courses are designed to form and support operational and dispatching staff stable skills in eliminating accident initiation and progression at substations, as well as system and intersystem complete power failure in the power grids of the Ukrainian UES. Also, these distance learning courses have already been introduced into the educational process of educational institutions, which are subordinated to the SE NEC “Ukrenergo” and the advanced training centre of the Ministry of Energy and Coal Mining of Ukraine.

We believe that it is advisable to conduct a staff professional development process using blended and distance learning technologies in approved virtual research and training centers. Virtual training centers will upgrade the existing personnel training system in the energy sector, taking into account the new electricity market model [32], maximum possible staff qualification quality, and save human and financial resources.

4.3 Virtual Centers for Training, Assessment, and Simulation System for Energy Professionals

When developing a network of virtual research and training centers for training personnel in the energy sector, it is necessary to fully employ all elements of the existing infrastructure of the personnel training system: material, technical, educational and methodological bases and teaching staff integrating it into a single information environment. Creating a comprehensive environment will allow using all the experience gained from the existing vocational simulating system in the energy sector and adapt the training programs to the needs of energy companies, the state and other stakeholders [3].

It is advisable to develop a network of virtual training centers in analogy with enterprise cloud computing. Virtualization is the main cloud computing technology and allows the creation of a single infrastructure of centers for personnel training, assessment and simulation system. Software tools developed to design, construct, and maintain a training facility of energy personnel simulating systems should support cloud architecture, virtualization, and blended and distance learning.

Nowadays, e-learning is widely used, therefore the software is being updated. There are several types of software products:

1. Copyright software. These are electronic textbooks, didactic materials, application software training packages and other elements of distance learning courses.

2. Content Management Systems. These include software products that support multiple users in a shared environment and are designed to create and modify digital content, such as text data, audio and video, program code, and more. The most well-known education-targeted content management systems with Ukrainian localization are Drupal and Joomla!

3. Learning Management Systems (LMS). LMS software is focused on learning activities management. The administration, documentation, tracking, and reporting functions are aimed at creating learning and development materials, and tasks such as providing training content to specific users at the right time, controlling the use of training resources, organizing interaction with the teacher, individual users and groups are automated. LMSs have the robust protection mechanisms required to deploy a distributed network of virtual training centers, can be synchronized with enterprise resource planning and personnel management systems. According to the research [1], the leaders are Blackboard, Canvas and Moodle software. Saba Software, SuccessFactors Learning, Voniz Inc., SumTotal Systems, Docent, WBT Systems, Click2Learn, and IBM are actively promoting their LMS products in the corporate market. Prometheus, Asnovator, Collaborator, and EDUGET worth mentioning among the products of the Ukrainian market.

4. Learning Content Management Systems (LCMS) are widely used in corporate computer networks. Unlike LMS, such systems focus on content management tasks, not the learning process, and are focused not on managers and students, but on content developers, methodological layout specialists, and project management executives. LCMS is based on the concept of presenting learning content as a collection of reusable learning objects with their target audience and specific context of use. Learning content management systems have only been actively implemented over the last few years, so the LSMS market is not mature enough, but the companies such as SAP (SAP Learning Solution), Oracle (iLearning and PeopleSoft Enterprise Learning Management) consider this type of e-learning not only as an infrastructure but also as part of the corporate IT infrastructure [3].

The LMS and LCMS systems discussed above have many things in common, as with the market expansion, LCMS developers are adding LMS-specific features and vice versa. LMS and LCMS have different goals: the main task of LMS is to automate the administrative aspects of learning, and LCMS is focused on managing the content of learning objects. The common features are the following: both systems manage the content of the courses and track the learning outcomes, the built-in tools can manage and track the content to the level of the learning objects. At the same time, LMS can manage and track blended learning outcomes that combine E-content, classroom activities, virtual classroom meetings, and other resources.

Based on the analysis of the existing open-source LMS/LCMS systems, according to the software selection criteria, Moodle (Modular Object-Oriented Dynamic Learning Environment) was chosen as the instrumental simulating environment of the virtual training systems in energy sector [16]. The Moodle system is designed to create quality distance courses; it is used in 100 countries around the world by universities, schools, companies, and independent teachers. In terms of functionality, Moodle successfully competes with well-known commercial learning management systems, such as Canvas and Blackboard, at the same time it differs from as it is distributed in open source, which makes it possible to localize it considering the features of a particular educational project. Moodle integrates easily with other systems; in particular, it allows downloading packages such as SCORM, IMS or AICC as an archive and add them to the course. Additional packages extend Moodle capabilities: for example, an IMS package can be used to present multimedia content and animation.

A competency-based approach to training and professional development of personnel, implemented on the basis of virtual technologies, will allow the staff of not only the energy sector but also of other branches of the economy of the country to master the most important competencies and independent assessment of the level of professional training. Also, the problem of possible loss of experience, skills, and knowledge of retired staff will be solved through the remote involvement of retired senior specialists - to develop scenarios of emergency response drills and training exercises, participation in distance courses, expert discussion of predicted emergencies triggering events, their types, and elimination measures, etc. [3].

The development and implementation of distance learning courses are aimed not only at working energy professionals but also at undergraduate and graduate students, who will be provided with all facilities and opportunities of e-learning and training (based on common models of large UES and EEA and use of modern modeling tools).

4.4 Creation of Objects and Scenarios of Simulating Systems

A computer simulator for operational and dispatching personnel of the EEA and UES of Ukraine is a training tool that provides staff with the opportunity to adequately simulate the specified operating modes and operating conditions of equipment in the training process. It is vitally important for the formatting key competencies, in particular, recognition of conditions and causes of accidents, as well as the formation of stable skills for the rapid elimination of accidents [3].

In the published work [23], a computer training system is defined as a set of computer simulators modeling different functions of real equipment of EEA and UES with high accuracy in normal and emergency situations aimed at the personnel educational process as a part of virtual research-educational centers (RECs). An important component of the computer training system is a simulation complex.

Currently, virtual technologies are not sufficiently involved in the development and use of mathematical, topological, information and computer models of simulating methods in distributed web-oriented environments [4, 5]. Such environments are often referred to as cloud computing, whose main purpose is to provide users with specific services [31]: OasS, IaaS, PaaS, etc.

Developing full-featured mode simulators for energy professionals (see Fig.1), including management staff, is a complex scientific and technical task. The simulating system includes certain subsystems: management of distributed databases; modeling of operating modes of power systems; visualization of simulation results; human-machine interface and automated system for creating scenarios of regular and emergency simulation [3]. The latter subsystem should ensure the rapid creation of emergency response drills, using materials of investigation or anticipation of accidents. The list of such scenarios that will form the methodological basis of the training facility of the personnel simulating system.

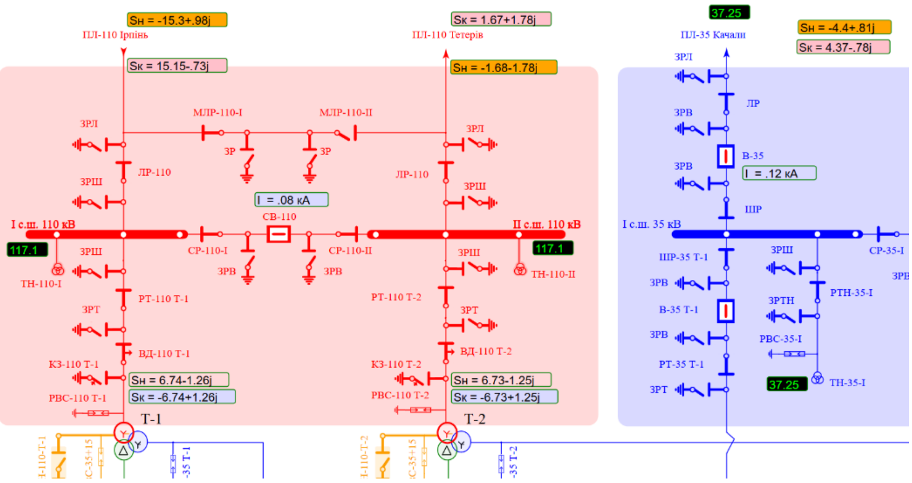

Fig. 1. An example of work full-featured mode simulators for energy professionals [9].

The published work [3] analyzes the existing approaches to the creation of training scenarios and the development of an automation system for the design of emergency response drills for remote web-oriented training simulators. The offered system of automation is intended for the organization of full training and methodological support of the personnel training process preparation both in the conditions of training centers and directly at workplaces. It is important to use a blended form of training around the clock for the operation and dispatching staff. The system of automated emergency response drills creation is realized taking into account features of the distributed environment of the power systems.

The main issue related to the simulating scenario design technology is the degree of completeness of the operational situations set that forms the basis of any personnel-training program. The experience of staff operational activity implies the importance of the instructor and training staff's personal experience when planning the training program. It is important to take an individual approach to staff training that allowing individually selecting content and planning a training program. The main difference between the proposed approach and the one described above is that the head of the simulation or training independently offers the conditions of the accident-triggering event. This allows focusing on the formation, control, and support of staff critical thinking skills and the ability to predict accident sequence. The generation of different possible or predicted options of situations greatly complements the algorithmic approach.

The publication [26] suggests a pedagogical scenario method of constructing simulation tasks based on the application of situational modeling methods. According to this method, the simulating complex and the object model - EEA and UES are used only at the development stage. The focus of the method is to create and use a model of personnel production activity according to job descriptions in the process of EEA and UES dispatch control. The scenario-simulating a pedagogical scenario method structure is formed as follows. After selecting the name, purpose, and task of the training task (TrT), a library of simulating procedures is created using the simulating complex (see Fig.2). The model of the operational and dispatching personnel activity is formed with the help of job descriptions, which regulate the required set of operations of dispatching control and are used as the object control model. It is advisable to use this method when designing the complex system and inter-system emergencies in terms of development and ways of elimination. Also when a possible alternative emergency development can lead to unexpected results in terms of the physical existence of the simulation modes.

The methods and algorithms of the formation of regression models of trunk electric grid (TEG) modes are developed, the ways of their use for the management problems solution within the process of carrying out the TrT of simulating systems (see Fig.3). This allows obtaining the results of simulation of different EEA and UES operational modes in the pace of time and with a comfortable reaction time required for the proper training. Comparative assessment of the first- and second-order regression models use for simulation of the modes allowed offering a convenient methodology for developing and organizing training systems and TrT models. This facilitates the work with the design and use features for the industry experts who have no programming skills. Switching programs can be written in the form of formal logical system for switching such as "run", "disable", "scan" and so on. This allows creating a task mini database to check the conditions of the performed or proposed operations in the form of a simple rule "if something happens or is completed, the result will be the following", which is then used to create emergency training scenarios and forms of routine switch cards [3].

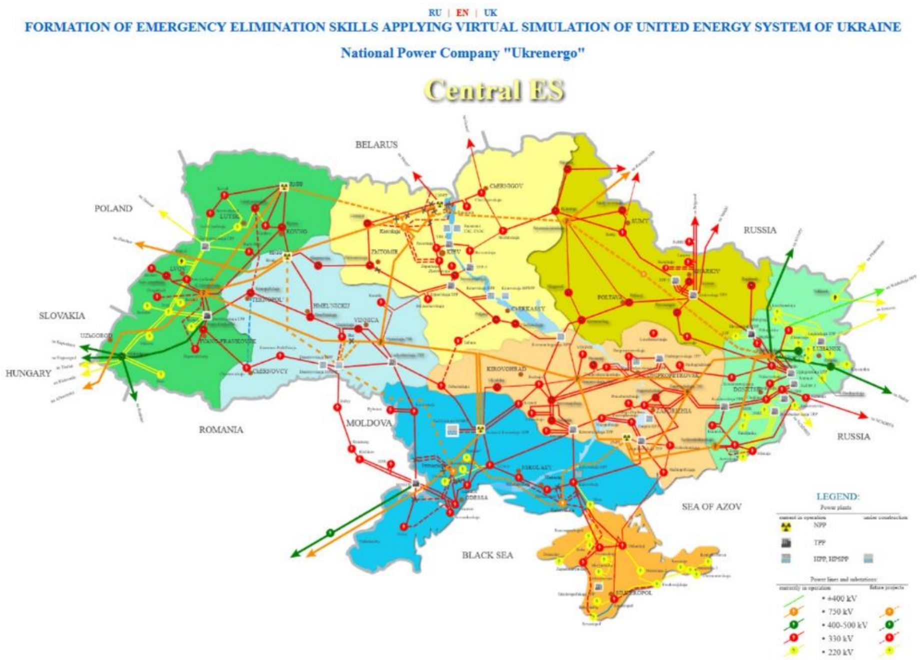

Fig. 2. Start page of full-scale simulator for operative staff.

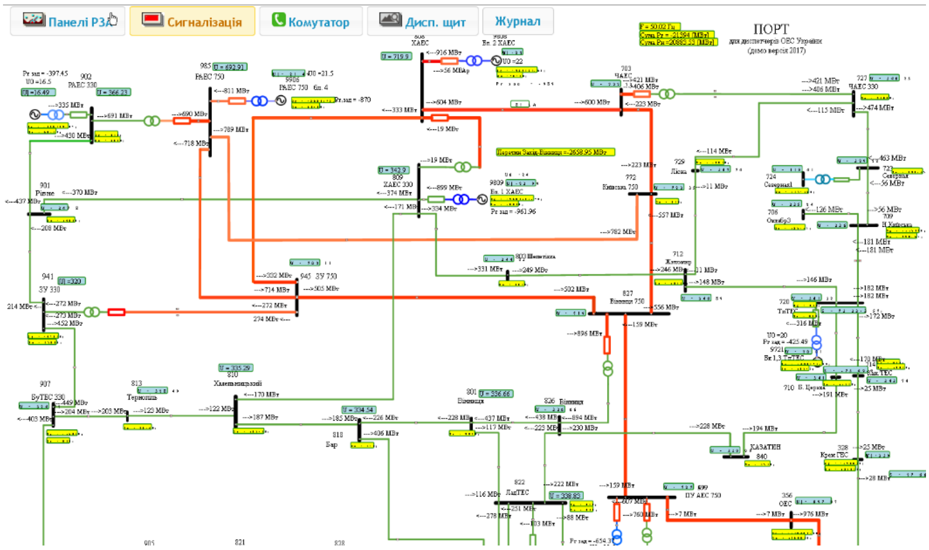

Fig. 3. An example of a large power systems scheme for constructing a TrT system.

The automation system of processes of design, editing, and creation of scenarios of regular and emergency training is developed for research and training virtual simulating centers. The proposed design system greatly speeds up the process of developing and creating (editing) emergency training scenarios. The distributed simulating environment provides ample opportunities for effective use of the new modern electronic system of work with personnel and allows to move to the development of uniform standards of personnel training and simulating system for the energy sector of Ukraine. The combination of modern e-learning methods and tools of distributed virtual simulating environment allows creating a new quality of the system of professional development and training of specialists in the field of energy, including operational personnel of substations and power systems.

The significant contribution to solving the described tasks by G.E. Pukhov Institute for Modeling in Energy Engineering of the NAS of Ukraine, the Institute of Electrodynamics of the NAS of Ukraine, the Data Processing Centre of the Main Technical Directorate, as well as the higher education institutions, such as the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" shall be noted.

4.5 The Main Modernization Aspects of the Personnel Professional Development and Training System in the Energy Sector

We agree with the statement [3] that the current crisis in the system of personnel professional development and training in the energy sector exists not only in Ukraine but also in the whole world. The main unsolved challenges of the current system of professional development in the energy sector are:

- there are no national standards for the vocational-technical training of personnel in specific professions in the energy sector;
- the large number of the energy industry professions operating a variety of energy equipment and the lack of its unification significantly limits the development of a common approach (common professional development standards) to the creation of modern and effective simulating systems and training of energy industry personnel as a whole and requires considerable resources;
- practically all training and professional development programs applied in the respective industry-specific colleges are outdated and are usually focused on specific theoretical or practical issues, usually not relevant to the operation of EEA and UES equipment, and are based on electrotechnical principles and not on EEA and UES information models in general;
- there is no open general information and modeling environment for carrying out full-fledged studies, analysis and forecasting of normal and emergency modes of operation of UES and EEA, including all existing levels of the management hierarchy as a whole, in order to use the results of studies and calculations for simulating systems;
- full-featured mode simulators operating at the Ukrainian NPPs are the effective means of professional development and training. However, they are quite expensive and oriented, as a rule, to the simulation of specific NPP energy equipment, which complicates the transfer and application of the learned skills to eliminate accidents to other similar parts of large UES and EEA;
- there are no appropriate simulators as well as an educational and methodological framework for the operational and dispatching staff;

- the problem of losing the experience, skills, and knowledge of retiring staff. The solution to this problem is possible through the remote involvement of retired specialists with extensive experience in developing scenarios of emergency training and simulating exercises, expert discussion of predicted accidents triggering events;
- the lack of accessible open web-based resources for obtaining structured competency-based knowledge, including professional development and training of teachers and instructors, with mandatory control of their level of competence;
- there is no proper operational and long-term psychophysiological examination (diagnostics) of the personnel, testing, system of vocational and social rehabilitation;
- there are no scientifically sound criteria for determining the level of reliability by means of accessible verification (control) of key competences of the personnel, providing the basic technological processes of generation, distribution, and consumption of electric and thermal energy;
- there are no industry-specific standards of personnel professional development and training in the energy sector;
- there are no procedures and criteria for real-time proficiency testing of staff using a modern advanced training system and guaranteed by teachers' level of competence.

5 Conclusions

Today, the greatest challenge for the sustainable development of modern civilization is the reliable operation of power systems to generate and distribute energy to consumers of the right quality in the right volumes. In Ukraine, the main unresolved problems of the current system of professional development of operational and dispatching personnel in the electric power industry are: unregulated legislative support; outdated material and technical support; teaching and learning materials requiring updating and development; the greater part of the staff are close to retirement age or already retired, therefore, there is a need for young staff. The problems listed above cannot be effectively solved only through the creation of new educational institutions, the training of additional highly qualified teaching staff and the development of new training programs and training courses. Affordable and equal opportunities must be created for the continuous training of personnel of all energy enterprises in the industry. The solution to these problems is possible through the creation of a unified global corporate online network, combining educational institutions and virtual centers and training facilities as well as personnel professional development systems in a single unified structure with one main management and responsible authority. This could also be implemented as part of the development of an international virtual simulating center for innovative technologies and energy personnel training.

References

1. 6th Annual LMS Data Update. Edutechnica. http://edutechnica.com/2018/10/06/6th-annual-lms-data-update/ (2018). Accessed 21 Mar 2020

2. Blinov, I.V., Parus, Ye.V., Ivanov, H.A.: Imitation modeling of the balancing electricity market functioning taking into account system constraints on the parameters of the IPS of Ukraine mode. Technical Electrodynamics **6**, 72-79 (2017). doi:10.15407/techned2017.06.072
3. Gurieiev, V., Sanginova, O., Avetisyan, E.: Metody modelyuvannya ta zasoby pobudovy i funktsionuvannya virtualʹnykh naukovo-navchalʹnykh tsentriv v enerhetytsi (Modeling Methods and means of construction and operation of virtual research and training centers in energy). VP «Edelʹveys», Kyiv (2019)
4. Gurieiev, V., Sanginova, O.: Simulation and study of modes for full-scale mode simulator for Ukrainian energy systems. In: Proceedings of the 2nd International Conference on Intelligent Energy and Power Systems (IEPS’2016), Kyiv, Ukraine, 7-11 June 2016, pp. 1–4. IEEE (2016). doi:10.1109/IEPS.2016.7521848
5. Gurieiev, V.O., Sanginova, O.V.: Distributed simulation environment of modes for full-scale mode simulator for ukrainianenergy systems. Technical Electrodynamics **5**, 67–69 (2016). https://doi.org/10.15407/techned2016.05.067
6. HKD 34.20.507-2003 Tekhnichna ekspluatatsiya elektrychnykh stantsiy i merezh. Pravyla (GCD 34.20.507-2003 Maintenance of power plants and networks. Rules). http://mpe.kmu.gov.ua/minugol/doccatalog/document?id=245088130 (2003). Accessed 21 Mar 2020
7. Iatsyshyn, Anna V., Kovach, V.O., Lyubchak, V.O., Zuban, Y.O., Piven, A.G., Sokolyuk, O.M., Iatsyshyn, Andrii V., Popov, O.O., Artemchuk, V.O.: Application of augmented reality technologies for education projects preparation. Proceedings of the 7th Workshop on Cloud Technologies in Education (CTE 2019), Kryvyi Rih, Ukraine, December 20, 2019, CEUR Workshop Proceedings (2019, in press)
8. Iatsyshyn, Anna V., Kovach, V.O., Romanenko, Ye.O., Deinega, I.I., Iatsyshyn, Andrii V., Popov, O.O., Kutsan, Yu.G., Artemchuk, V.O., Burov, O.Yu., Lytvynova, S.H.: Application of augmented reality technologies for preparation of specialists of new technological era. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR Workshop Proceedings **2547**, 181–200. http://ceur-ws.org/Vol-2547/paper14.pdf (2020). Accessed 21 Mar 2020
9. Infotec Ltd. http://www.infotec.ua/ Accessed 21 Mar 2020
10. Jeong, K., Choi, B., Moon, J., Hyun, D., Lee, J., Kim, I., Kim, G., Kang, S.: Risk assessment on abnormal accidents from human errors during decommissioning of nuclear facilities. Annals of Nuclear Energy **87**(P2), 1–6 (2016). https://doi.org/10.1016/j.anucene.2015.08.009
11. Kabinet Ministriv Ukrainy: Pro skhvalennya Enerhetychnoyi stratehiyi Ukrayiny na period do 2035 roku “Bezpeka, enerhoefektyvnistʹ, konkurentospromozhnistʹ” (On approval of the Energy Strategy of Ukraine for the period up to 2035 “Security, energy efficiency, competitiveness”) https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80?lang=en (2017). Accessed 21 Mar 2020
12. Kukharenko, V.: Massive open online courses in Ukraine. In Proceedings of the 2013 IEEE 7th International Conference on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS’2013), Berlin, Germany, 12-14 Sept. 2013, Vol. 2, pp. 760–763. IEEE (2013). https://doi.org/10.1109/IDAACS.2013.6663027
13. Kutsan, Y., Gurieiev, V., Iatsyshyn, Andrii, Iatsyshyn, Anna, Lysenko, E.: Development of a virtual scientific and educational center for personnel advanced training in the energy sector of Ukraine. Studies in Systems, Decision and Control. Springer, Cham. (2020, in press)

14. Kyrylenko, O.V., Blinov, I.V., Parus, Y.V., Ivanov, H.A.: Simulation model of day ahead market with implicit consideration of power systems network constraints. Technical Electrodynamics **5**, 60 – 67 (2019). doi:10.15407/techned2019.05.060
15. Ministerstvo palyva ta enerhetyky Ukrayiny: "Orhanizatsiya roboty z personalom pidpryyemstv elektroenerhetyky. Polozhennya" (SOU-N MPE 40.1.12.104:2005) ("Organization of work with the personnel of the electric power enterprises. Regulations" (SOE-H MPE 40.1.12.104:2005)). http://mpe.kmu.gov.ua/minugol/doccatalog/document?id=245088024 (2016). Accessed 21 Mar 2020
16. Mintii, I.S., Shokaliuk, S.V., Vakaliuk, T.A., Mintii, M.M., Soloviev, V.N.: Import test questions into LCMS Moodle. In: Edited by: Kiv A.E, Soloviev V.N. Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 529–540. http://ceur-ws.org/Vol-2433/paper36.pdf (2019). Accessed 21 Mar 2020
17. Modlo, Y.O., Semerikov, S.O., Bondarevskyi, S.L., Tolmachev, S.T., Markova, O.M., Nechypurenko, P.P.: Methods of using mobile Internet devices in the formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR Workshop Proceedings **2547**, 217–240. http://ceur-ws.org/Vol-2547/paper16.pdf (2020). Accessed 21 Mar 2020
18. Modlo, Y.O., Semerikov, S.O., Shmeltzer, E.O.: Modernization of professional training of electromechanics bachelors: ICT-based Competence Approach. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018) Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2277**, 148–172. http://ceur-ws.org/Vol-2257/paper15.pdf (2018). Accessed 21 Mar 2020
19. Okhotin, V.V., Khoziyev, V.B.: Sovremennyye tendentsii trenazherostroyeniya i komp'yute-rizatsii podgotovki personala energoblokov (Current trends in simulator building and computerization of personnel training at power units). Elektricheskiye stantsii **10**, 23-27 (1994)
20. Popov, O., Iatsyshyn A., Kovach, V., Artemchuk, V., Taraduda, D., Sobyna, V., Sokolov, D., Dement, M., Yatsyshyn, T., Matvieieva, I.: Analysis of Possible Causes of NPP Emergencies to Minimize Risk of Their Occurrence. Nuclear and Radiation Safety **1**(81), 75-80 (2019). doi:10.32918/nrs.2019.1(81).13
21. Popov, O., Iatsyshyn, A., Kovach, V., Artemchuk, V., Taraduda, D., Sobyna, V., Sokolov, D., Dement, M., Yatsyshyn, T.: Conceptual Approaches for Development of Informational and Analytical Expert System for Assessing the NPP impact on the Environment. Nuclear and Radiation Safety **3**(79), 56–65 (2018). doi:10.32918/nrs.2018.3(79).09
22. Popov, O., Iatsyshyn, A., Kovach, V., Artemchuk, V., Taraduda, D., Sobyna, V., Sokolov, D., Dement, M., Hurkovskyi, V., Nikolaiev, K., Yatsyshyn, T., Dimitriieva, D.: Physical Features of Pollutants Spread in the Air During the Emergency at NPPs. Nuclear and Radiation Safety **4**(84), 88-98 (2019). doi:10.32918/nrs.2019.4(84).11
23. Power Systems glossary. IBM Knowledge Center. https://www.ibm.com/support/knowledgecenter/9119-MME/p8hav/glossary.htm#gloss_V (2017). Accessed 21 Mar 2020
24. Proskura, S.L., Lytvynova, S.G.: Organization of independent studying of future bachelors in computer science within higher education institutions of Ukraine. In: Edited by: Ermolayev V., Suárez-Figueroa M.C., Yakovyna V., Kharchenko V., Kobets V., Kravtsov H., Peschanenko V., Prytula Y., Nikitchenko M., Spivakovsky A. Proceedings of the 14th In-

ternational Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops (ICTERI 2018), Kyiv, Ukraine, May 14-17, 2018. CEUR Workshop Proceedings **2104**, 348–358. http://ceur-ws.org/Vol-2104/paper_160.pdf (2018). Accessed 21 Mar 2020

25. Rashkevych, Yu.M.: Kompetentnisnyy pidkhid v pobudovi navchalʹnykh prohram (Competent approach in curriculum development). https://www.tempus.org.ua/uk/korysna-informacija/prezentaciji/781-rashkevych-competence-approach-20-09-2012/download.html (2012). Accessed 21 Mar 2020
26. Samoylov, V.D.: Osnovy avtomatizirovannogo postroyeniya trenazherno-obuchayushchikh sistem i sistem professional'noy diagnostiki (Fundamentals of the automated construction of training and training systems and professional diagnostic systems). Naukova dumka, Kyiv (1990)
27. Spada, M., Paraschiv, F., Burgherr, P.: A comparison of risk measures for accidents in the energy sector and their implications on decision-making strategies. Energy **154**, 277–288 (2018) https://doi.org/10.1016/j.energy.2018.04.110
28. Spirin, O., Oleksiuk, V., Balyk, N., Lytvynova, S., Sydorenko, S.: The blended methodology of learning computer networks: Cloud-based approach. In: Ermolayev V., Mallet F., Yakovyna V., Kharchenko V., Kobets V., Korniłowicz A., Kravtsov H., Nikitchenko M., Semerikov S., Spivakovsky A. (eds.) Proceedings of the 15th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops (ICTERI-VOL-2-2019), Kherson, Ukraine, June 12-15, 2019. CEUR Workshop Proceedings **2393**, 68–80. http://ceur-ws.org/Vol-2393/paper_231.pdf (2019). Accessed 21 Mar 2020
29. Stratehiya reformuvannya DP "NEK "Ukrenerho" (Reform Strategy of SE "NPC "Ukrenergo"). https://www.slideshare.net/Ukrenergo/ss-102780816 (2018). Accessed 21 Mar 2020
30. Syaber, N.A., Gurieiev, V.A.: Primeneniye sovremennykh trenazhernykh tekhnologiy dlya obucheniya personala v energetike Ukrainy (The use of modern training technologies for staff training in the energy sector of Ukraine). Energetika i elektrifikatsiya **6**, 45-50 (2005)
31. Tipy oblachnykh vychisleniy (Types of Cloud Computing). https://aws.amazon.com/types-of-cloud-computing/?WICC=tile&tile=types_of_cloud (2020). Accessed 21 Mar 2020
32. Zakon Ukrayiny: Pro rynok elektrychnoyi enerhiyi Ukrayiny (About the Electricity Market of Ukraine). https://zakon.rada.gov.ua/laws/main/2019-19 (2017). Accessed 21 Mar 2020
33. Zaporozhets, A., Eremenko, V., Serhiienko, R., Ivanov, S.: Methods and Hardware for Diagnosing Thermal Power Equipment Based on Smart Grid Technology. In: Shakhovska, N., Medykovskyy, M. (eds) Advances in Intelligent Systems and Computing III. CSIT 2018. Advances in Intelligent Systems and Computing, vol. 871, pp. 476-489. Springer, Cham (2019). doi:10.1007/978-3-030-01069-0_34.
34. Zaporozhets, A., Kovtun, S., Dekusha, O.: System for Monitoring the Technical State of Heating Networks Based on UAVs. In: Shakhovska N., Medykovskyy M. (eds) Advances in Intelligent Systems and Computing IV. CCSIT 2019. Advances in Intelligent Systems and Computing, vol 1080. Springer, Cham (2020). doi:10.1007/978-3-030-33695-0_61