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DEVELOPMENT TRENDS FOR ENGINEERING EDUCATION IN THE SPHERE OF SMART GRIDS: INTERDISCIPLINARY APPROACH

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Abstract. The experience in the creation of modern educational programs for engineers in the field of smart grids at National Research Tomsk Polytechnic University for the past three years has shown the need for upgrading a basic technical education through the initiation of interdisciplinary courses such as Systems Engineering, Policy Analysis and Management. Another way is the organization of Master Program for Systems Engineering for all students, graduated from technical baccalaureate programs. The latter initiative has been developed in the elaboration of master's program "System analysis and management" (according to the Russian education standard), which was agreed with the standards of international SEPAM program (Systems Engineering, Policy Analysis and Management). The project have been presented at the annual forum where top managers of large and medium-sized Russian companies were interviewed about present-day engineer priority qualities. The results showed that the leaders of the industry share the view that in order to overcome the economic stagnation the technical education should combine competencies of systems thinking and multidisciplinary approach. These contributions are valid for the training of engineers for smart grids. It requires the further research for other sectors of the economy and industry in the Russian Federation.

Keywords: economy, industry, stagnation, smart grids, education, competencies, interdisciplinary approach, systems thinking.

Introduction. The higher education system, which forms the future engineers on whose activity is directly related security and sustainable development of civilization, is obliged to impart to students of technical specialties humanistic and interdisciplinary way of thinking, because the application of scientific results is the question

of morality, ethics and politics and always located in the area of human choice. To solve the problem of innovative economy development, coupled with the introduction of modern technologies and scientific achievements in the practice of social life, it is necessary to ensure the training of specialists capable of being based on a systematic and interdisciplinary approach to integrate the knowledge of the technical, humanitarian and socio-economic sciences, create and manage a complex, large-scale systems.

The amount of this type of systems is increasing, and the systems themselves exceed historical analogies, both in the complexity of factors affecting system management, and to a scale of the involvement of diverse organizations and even States. The increasing complexity of control systems is accompanied by a rapid and poorly predictable changes in the environment [1]. Application of Systems Engineering methods provides a mean to administer to needs of all interest groups, to minimize departure from a target plan [2]. In the last decade, a systems engineer profession has become one of the most prestigious and promising in the USA, surpassing the usual leaders in the fields of law, finances, IT and smart grids. In the Russian rankings of well-respected scholarship such profession does not figure.

Methods and research design. Monitoring of employers requirements for competence of the contemporary engineer in Russia and other countries indicates the relevance of specific training for professionals in technical sphere teaching to apply the systematic and interdisciplinary approach in the practice. Besides, the specifics of Russian and foreign universities educational programs, state federal educational standard provide an opportunity for the development of basic educational training program in the field of system analysis and management of socio-technical systems on the basis of a multidisciplinary approach for all sectors of the modern economy.

Since 2012, Tomsk Polytechnic University has been beginning to develop an educational program in the field of system analysis and control for the training of the engineering staff. The important point is the combination of the fundamental methods of system design, analysis and management with the application of knowledge aimed at the implementation of the methodology in a particular kind of activity. The first stage in designing the content of training programs for the contemporary engineer was to analyze the best educational practices in the field of systems engineering. As a result, authors came to reach the conclusion that the leader institutions of higher education in this field are Massachusetts Institute of Technology [3] and Delft University of Technology [4]. In the Russian education the state educational standard "System Analysis and Management" is developed [5].

Analysis of Master's programs has shown that the goal of the educational program is to train engineers to design-analytical and managerial activity aimed at modeling, production and operation of large-scale systems in the multi-disciplinary professional team environment. For taking a professional decisions specialist should be able to exercise the choice of optimal solutions and to develop an experimental research programs, to make the description of ongoing project and research work on an interdisciplinary language that is understandable to all members of the team, to issue reports, to master methods of intellectual property protection, to explore and take into account the needs of all engaged participants [6; 7].

The specification of project research work forms during the semester for Masters's Program students may be itemized and supplemented depending on the specifics of subject field. The head of the master's program establishes a mandatory list of research forms (do not forget about the need to obtain credits for research work during the semester) and a character of student's participation in the research work during the all training period.

Approval. To pilot the contribution of the Tomsk Polytechnic University in the sphere of System Engineering two events were initiated: the methodical international seminar involving experts from the Technical University of Delft and the workshop at the annual forum of directors of medium and large Russian enterprises.

Within the framework of the international methodological seminar participants discussed the theoretical base of the educational program for the engineers training and work programs of 15 disciplines included in the curriculum. As a result, the recommendation was given to change the proportion between the theoretical and practical parts of training in favor of the second. The technology efficiency of modern specialists training suggests the ratio of practically-oriented project activities and theoretical study on the level 70% to 30% respectively. In addition, the theoretical work can be effectively organized in the form of a self-guided work, tutorials and remote training. The main attention should be focused on project activities pursued an obtaining of professional experience. This trend is not conventional for the education of Russian engineers. Traditionally, theoretical preparation took up about 50-60% of training time here. From higher education institutions this turn requires to develop new information technologies and intense cooperation with business organizations.

The seminar at the annual forum of medium and large enterprises heads of the Russian Federation the pilot Master's Program in System Engineering was represented and 10 directors of major Russian companies were interviewed on this subject. The questionnaire included five sets of interrogations: the drivers of the external environment for the enterprise, ways of solutions to the problems of the contemporary enterprise, evaluation of the enterprise specialists the contribution in the work of the enterprise, the competence of modern engineering personnel, the interest of enterprises in the target training of future staff.

Research Results. Interviews approved that directors of large companies believe that their companies are in the process of stabilization of the life cycle, as the main responsibilities they see the improvement of products quality and the introduction of a systematic approach to gain competitive advantage in the Russian market by contrast to imported products. Current development of the enterprise they are linked with the development of human resource capacity, able to work in team/in project, and a systematically apply the multidisciplinary approach in order to reduce their risks.

In assessing of educational programs for specialist training the business community indicated that the development of systems thinking, skills of policy analysis and production management is an extremely important for educational background of all engineers. They do not consider expedient to include individual specialist in the systems engineering in the staffing positions. They also estimate as a significant the

application of the principles of systems engineering, policy analysis and management to the design of special professional activities.

Thus, the approbation has demonstrated that the training of specialists in the direction of separate Master's Program "System analysis and management" is not corresponding to the social mandate. Business Community proposes to change the basic structure of the training programs. Design of an engineer training should be focused in the formation of systems thinking, systems engineering skills and interdisciplinary approach to increase in hours for practical work and seminars. Thus, it is proposed to include the module –transformer, forming skills of System Analysis in the basic educational training program both in the compulsory and the elective parts.

The elective part of the program aimed at the formation of the system thinking and skills of interdisciplinary analysis. The compulsory part of the program should be directed to the formation of special professional knowledge. If the structure of the labor market needs is changing, it is possible to reorient the selected part of the educational program actualizing new profiles. The idea of the program-transformer was initiated by employers, who showed in the process of a sociological study that for all kinds of enterprise the knowledge and skills associated with a system an interdisciplinary thinking are important together with a preserving the compulsory part of the training in the major field of study (smart grids, cybernetics, energy).

The actualization of the program involves an interdisciplinary parity representation of humanitarian, socio-economic and technical institutions profiles for training. Humanitarian and socio-economic units are designed to provide two-semester disciplines of selected part of educational programs aimed at the formation of the systems and interdisciplinary thinking. Technical departments participated in the provision of multi-disciplinary research work during first two semesters, and provide the basic specialization training in the third term. Preparation of final qualifying paper carried out under the joint advising of the leading specialists in humanitarian, socio-economic and technological sphere.

Conclusion. Thus, the structure of a basic educational program should include a compulsory and a selected parts, presenting a program-transformer. The compulsory part of the program aimed at the formation of the system such as thinking skills and interdisciplinary analysis. The elective part of the program aimed at forming of the system thinking and skills of interdisciplinary method in the light of smart grids specific features. If the structure of the labor market needs are changed, the reorientations of the educational program variable part to actualize the new specializations will be possible. The idea of the program-transformer was initiated by employers, who showed in the course of interview, all the sectors of industry, small and medium business are interested in the knowledge and skills associated with the system and interdisciplinary type of thinking. However, the employers prefer engage the graduates from basic engineers programs with an auditory competences of system thinking rather than support the idea of autonomy program in System Engineering.

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DEVELOPING DEEP LEARNING COMPETENCIES IN ENGINEERING EDUCATION

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In the 21st century engineering is seen both as an art and a science. The science comprises the careful and knowledgeable use of scientific principles, physical materials, and design techniques to produce devices and systems, and their operating arrangements, to perform useful functions in a reliable and affordable way. These can range from smart grids to computer networks; from mobile phone applications to intelligent meters; from motor drives to wireless credit cards. The art lies in creating new directions in human activities by perceiving non-traditional applications of scientific knowledge, combining different fields of knowledge in unique ways, introducing new technologies and managing a variety of technical resources to produce innovative outcomes.

In other words, engineering is about developing, providing and maintaining infrastructure, goods and services for industry and the community, and about helping to identify and implement directions for sustainable future. Professional engineers normally work in interdisciplinary teams and are supposed to cope with risks and take social responsibility for the results of engineering projects. New pedagogies for deep learning that are available in the 21st century are aimed at training specialists prepared to work creatively in the global economic community and respond to the unpredictable challenges of the time for the sake of the stable and sustainable development [1, 2].

Deep learning skills (also termed as 21st century skills and competencies) are composed of 4 groups of skills, which include: ways of working: communication and