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Managerial Aspects of Training Electrical Power Supply Specialists in the Context of Decentralization and "Green" Transition

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ABSTRACT

This article presents a comprehensive study of the management aspects necessary for modernizing the training of engineering personnel specializing in the "Power Supply" discipline, amidst unprecedented transformational challenges. These challenges are determined by the decentralization of the national energy system and the acceleration of the global "green transition," which fundamentally alters the specialist's professional profile. Focusing on the critical need for entirely new competencies, the paper structurally covers and analyzes four key management areas of university activity: educational content, material and technical resources, human capital, and interaction with industry. Based on the application of systemic, comparative-analytical methods and expert evaluations, sharp discrepancies between the academic offering and the rapidly changing demands of the modern energy market are identified. Management problems are analyzed in detail, including the determined factors driving the outflow of highly qualified lecturer-practitioners and the critical issue of obsolete laboratory infrastructure, which prevents quality training in technologies such as Smart Grids and distributed generation. The article justifies the need for prompt content actualization of the "Power Supply" discipline through the integration of modules dedicated to digitalization, cybersecurity, and DC power networks. Management solutions are proposed for developing a holistic structure for the modernization system, including tools for financially stimulating lecturer-practitioners and, most importantly, mechanisms for creating joint educational and research centers on a partnership basis with leading energy companies. The implementation of these recommendations will provide the industry with specialists ready to work in an innovative and technologically complex energy environment.

KEYWORDS

"Power Supply" (electric power systems), human capital management, green transition, educational content actualization, university-industry cooperation.

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Публічне управління і політика

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Управлінські аспекти підготовки фахівців з електропостачання в умовах децентралізації та «зеленого» переходу

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СТАТТЯ

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АНОТАЦІЯ

У статті здійснено комплексне дослідження управлінських аспектів необхідної модернізації підготовки інженерних кадрів, що спеціалізуються на дисципліні «Електропостачання», в умовах безпрецедентних трансформаційних викликів. Ці виклики детерміновані децентралізацією національної енергосистеми та прискоренням глобального «зеленого» переходу, що кардинально змінює професійний профіль фахівця. Акцентуючи увагу на критичній потребі в абсолютно нових компетентностях, робота структурно охоплює та аналізує чотири ключові управлінські сфери університетської діяльності: зміст освіти, матеріально-технічну базу, людський капітал та взаємодію з виробництвом. На основі застосування системного, порівняльно-аналітичного методів та експертних оцінок, виявлено гострі розриви між академічною пропозицією та швидкозмінними вимогами сучасного енергетичного ринку. Детально проаналізовано управлінські проблеми, зокрема визначено чинники відтоку висококваліфікованих викладачів-практиків і критичну проблему застарілості лабораторної бази, що унеможливлює якісне навчання роботи з технологіями Smart Grids та розподіленої генерації. Запропоновано управлінські рішення для розробки цілісної структури системи модернізації, включно з інструментами фінансового стимулювання викладачів-практиків та, що найважливіше, механізмами створення спільних навчально-дослідних центрів на партнерських засадах із провідними енергетичними компаніями. Реалізація цих рекомендацій забезпечить галузь фахівцями, готовими до роботи в інноваційному та технологічно складному енергетичному середовищі.

КЛЮЧОВІ СЛОВА

електропостачання, управління людським капіталом, зелений перехід, актуалізація змісту освіти, взаємодія «університет-виробництво».

1. Introduction

The urgency of the problem of improving the efficiency of training of electricity supply specialists in the context of decentralization and the "green" transition is due to factors that radically change the global energy landscape. This is not just a technological shift, but a complex transformation that requires a rethinking of the entire system of vocational education.

The traditional energy system on which 20th-century industry and infrastructure were based was built on a top-down model. Huge centralized power plants (thermal, nuclear, hydroelectric power plants) transmitted energy through extensive networks to end consumers. Education in the field of electricity supply was accordingly focused on the design, operation, and management of just such systems.

However, modern energy tends to decentralize, which implies a transition to a bottom-up model. Energy is increasingly produced by thousands of small and medium-sized facilities: solar power plants, wind turbines in local communities, and small power generators. This process is closely related to the "green" transition – the massive introduction of renewable energy sources (RES). Such a transformation creates new challenges that traditional education cannot ignore. Future energy engineers must be able to manage unstable energy flows, integrate RES into existing grids, and work with intelligent control systems (Smart Grids) that automatically optimize energy distribution.

University management faces urgent problems: updating educational programs and adapting to the realities of the "green" transition, finding sources of funding for the process of modernization of the material and technical base, and attracting qualified scientific and pedagogical workers who have up-to-date experience in working with modern technologies. Delaying these challenges can lead to a loss of competitiveness not only for individual educational institutions but also for the entire energy sector of the country, since the shortage of qualified personnel can slow down innovative development.

Thus, the relevance of the topic goes far beyond purely educational issues. It deals with national security, economic growth, and sustainable development, making it critical for scientific research and practical implementation.

2. Literature Review

Conducting a comprehensive study of managerial aspects of modernization of the training of engineering personnel specializing in the discipline "Power Supply" required the involvement of a wide range of relevant scientific and analytical sources.

The fundamental justification for the need for change is provided by sources describing global and national imperatives. Decentralization of the energy system as a key challenge is highlighted in the work by V. Kudrytskyi [4]. This process directly requires the integration of knowledge about distributed generation, which is the central topic of research by L. Bilozerova [1].

The need to actualize the content of education as a management function is confirmed by works that analyze the dual (digital and green) transition [3] and the smart transformation of energy and Smart Grids [2]. Direct methodological recommendations for the implementation of innovative approaches to the training of engineers are provided in [15]. Separately, the issue of integrating knowledge about cybersecurity in the energy sector was studied [10], which is a critical element of the modern content of the discipline "Power Supply".

The problems of human capital management (in particular, the outflow of teachers-practitioners) are revealed in the publication by V. Kukharsky [7].

Since the solution of the personnel problem requires financial stimulation and updating the material and technical base, works on the management of university finances and models of their financing were studied [5; 16]. These sources provided an economic basis for the development of managerial decisions regarding the resource base.

The management of the university's interaction with production is based on the need to establish a strategic partnership. This mechanism is the key to solving the problems of the personnel and material base. The study by I. Yashchyshyna [20] highlights ways to optimize research cooperation between businesses and universities. This made it possible to justify the creation of joint training and research centers. The works of O. Patlaichuk and I. Briukhovetska [14], which consider the individualization of

the educational process, which is effectively implemented through partner internship programs in production, were also taken into account.

Thus, a review of literature sources confirms that the article has a solid theoretical basis, which comprehensively covers all managerial aspects of modernization of the training of specialists in "Power Supply" in the face of modern challenges.

3. Problem Statement

The purpose of this article is to scientifically substantiate and develop a system of management decisions for modernizing the process of training electricity supply specialists in the context of decentralization and green transition, which includes improving the content, staffing and interaction with production, ensuring the formation of an engineering corps capable of implementing energy transformations in Ukraine.

4. Methods and Materials

The study of managerial aspects of training specialists specializing in the discipline of "Power Supply" is based on an integrated approach that combines a deep analysis of theoretical foundations and the collection of empirical data.

The materials for the analysis were formed from several key sources. First of all, the regulatory framework of Ukraine regulating higher education, as well as documents outlining the vectors of decentralization of the energy system and accelerating the green transition, were studied. This made it possible to identify external imperatives that dictate new requirements for specialists.

A detailed analysis of the content of the discipline "Power Supply" was carried out to identify its compliance with current technological requirements. The theoretical basis of the study was strengthened by scientific publications – domestic works on human capital management in the field of engineering education and the organization of effective management of the material and technical base.

To achieve this goal, a set of complementary scientific methods was used. System analysis and synthesis served as the basis for structuring the managerial aspects of training (content of education, material base, human capital, and interaction) and the formation of a holistic concept of modernization in the face of new energy challenges. To collect empirical data on the real effectiveness of current training, the method of expert assessments was used, which made it possible to establish the reasons for the outflow of teachers-practitioners and assess the urgent needs of the production sector. Finally, the methods of induction and deduction provided a logical transition from the analysis of specific management problems (for example, the obsolescence of laboratory equipment) to the formulation of general management conclusions and practical recommendations for university management.

5. Results and Discussion

The green transition is not just an environmental trend, but a new paradigm of economic development. Countries that actively invest in clean energy create new jobs and strengthen their energy independence. This process requires a highly qualified talent pool. The inability of universities to provide such training can slow down investment projects and create a critical personnel shortage in the industry [3].

In addition, decentralization and digitalization of energy systems pose new security challenges. Smart grids, while effective, are also becoming potential targets of cyberattacks. Therefore, future power supply professionals must have in-depth knowledge of cybersecurity and risk management. This requires universities not only to make technical, but also strategic management decisions to integrate these topics into curricula [6].

It should be noted that not always existing educational programs in higher education institutions in Ukraine often remain focused on outdated technologies and models, which leads to a critical gap between what is taught and what is required in the labor market. Graduates usually receive thorough theoretical knowledge of classical electrical engineering, but quite often they do not have the necessary practical skills: microgrid design, understanding of the operation of energy storage systems, and knowledge of the basics of cybersecurity of power systems [19].

It should be noted that the ability of educational programs to quickly adapt to changes in technologies and the needs of the labor market in modern conditions is realized through the flexibility of the educational process [8]. This flexibility in the training of electricity supply specialists in Ukrainian universities is achieved through the modular construction of curricula, individualization of training and close interaction with industry. This helps to solve the problem of obsolescence of knowledge, which is critical in such a dynamic industry as energy.

Among the components of flexibility of the educational process, it is necessary to highlight:

- Modular approach – instead of a rigid curriculum, the program is divided into separate, self-sufficient training modules. This allows you to quickly add new courses related to modern topics like distributed generation, smart grids, and cybersecurity. Students can choose modules that meet their interests, forming their own educational trajectory.
- Individualization of learning – flexibility allows students to choose a significant part of the courses. This makes it possible to study in depth narrow specializations that are relevant for specific employers, as well as to adapt training to personal needs and career goals [14].
- Integration with industry – flexibility implies a constant dialogue between universities and energy companies. Employers can participate in the development of modules, conduct practical classes and internships, which ensures that the content of education meets the real needs of the market.

Regular monitoring of labor market requirements through consultations with energy companies is critical to ensure the relevance of educational programs on electricity supply. In addition, such monitoring will significantly increase the employment rate of graduates, because students whose knowledge and skills meet the requirements of employers find a job faster and adapt more successfully to professional activities [13]. An educational institution that trains in-demand specialists becomes more attractive to applicants and employers, which contributes to its development and strengthens its position in the market of educational services, increasing its reputation.

We believe that a serious problem in the training of electricity supply specialists is the lack of specialized courses on distributed generation, smart grids and cybersecurity of power systems in electrical engineering training programs. This results in graduates lacking the up-to-date knowledge and skills needed to work in today's rapidly changing energy industry under the influence of technological advancements.

The lack of courses on distributed generation does not allow students to properly understand the principles of functioning of local energy systems, including renewable energy sources (solar, wind farms), cogeneration plants and energy storage systems. In the context of the decentralization of Ukraine's energy system, which has become especially relevant after the full-scale invasion, this knowledge is critically important [11]. Graduates often do not know how to design, connect and operate such systems, which creates a shortage of qualified personnel [1].

Without courses on smart grids, future specialists do not master the knowledge of automation, digitalization, and optimization of power grids. This involves studying monitoring systems, managing demand, and integrating various generation sources into a single network. Traditional applications focused on classical approaches to working with centralized networks do not meet the needs of the modern market, where IoT (Internet of Things) and Big Data technologies are widespread [2].

Modern energy systems are highly automated and digital, which makes them vulnerable to cyberattacks. Graduates who do not have knowledge of industrial systems protection (OT/ICS), threat detection and incident response techniques cannot ensure the security of energy infrastructure. This gap in education threatens not only the work of individual enterprises, but also national energy security [10].

The implementation of interdisciplinary courses that combine power supply with IT, automation, and economics is critical to the training of today's engineers. This allows graduates to understand not only technical aspects, but also to effectively work with smart grids, automated systems, and assess the economic feasibility of projects. Such specialists are versatile and more competitive in the labor market.

In the current conditions of martial law and the critical financial and economic situation of Ukraine, the problem of managing the material and technical base (MTB) in the training of specialists in electricity supply in domestic institutions of higher education becomes especially acute. This issue goes beyond simply upgrading equipment – it concerns the ability of universities to train power engineers who will be able to work in modern conditions, and not with technologies of the last century [4].

The primary problem is the catastrophic obsolescence of the existing MTB. Laboratories designed to study the basics of power supply are often equipped with equipment that was released several

decades ago. Students work with analog devices, mechanical protection relays and outdated transformers, while modern energy has long switched to digital technologies. This creates a significant gap: a graduate who has theoretical knowledge but no practical experience with modern SCADA systems, digital relays and other intelligent devices is not ready for the challenges of real production.

A serious problem is the lack of funding. MTB modernization is an extremely expensive pleasure. Modern laboratories require serious investments in simulation software, simulators, test benches for Smart Grids, equipment for the study of renewable energy sources, etc. Budget funding allocated for these needs is scarce, which makes it impossible to fully purchase everything necessary [16].

In conditions of limited funding, universities cannot afford to upgrade equipment, which leads to a vicious circle of problems: outdated equipment → irrelevant knowledge → uncompetitive graduates → weak cooperation with business → lack of investment [18].

As a result, the quality of practical training suffers. Instead of working in laboratories that simulate real conditions, students are forced to perform laboratory work on outdated equipment that does not meet safety and efficiency standards. This not only does not give them the necessary skills, but can also lead to the formation of incorrect ideas about modern technological processes.

To overcome the negative trends regarding the critical situation with the financing of the educational process of training specialists in the power supply of the university management, special attention should be focused on:

- close cooperation with energy companies – higher education institutions can attract business to finance laboratories. Energy companies are interested in qualified personnel, so investing in education can be profitable for them. Joint laboratories equipped with equipment from partner companies are an effective solution;
- creation of virtual and augmented laboratories – the use of modern IT technologies allows you to partially solve the problem by creating virtual simulators and models. This is much cheaper than real equipment, and students can practice skills in a virtual environment that simulates real conditions [13];
- state and international funding – attracting grants and state programs aimed at updating educational infrastructure is key to overcoming this challenge.

Success in overcoming these problems depends on the readiness of all stakeholders – the state, educational institutions and business – to join forces and introduce innovative approaches to the management of the educational process [5].

The success of the training of power engineers critically depends on who and how teaches key specialized subjects.

The main personnel problem is the outflow of highly qualified teachers-practitioners. Specialists with real experience in the field of operation and design of power supply systems rarely stay in the academic environment. Energy companies and the private sector offer them significantly higher salaries and better conditions, creating a staff shortage among the teaching staff [9]. This leads to the fact that students often do not receive first-hand knowledge.

This is closely related to the lack of actualization of knowledge among the remaining scientific and pedagogical workers. Even experienced teachers do not always have the resources or systematic opportunities for regular internships on modern equipment. As a result, the material taught may be based on outdated norms and technologies, not reflecting industry best practices, such as the digitalization of substations, the integration of Smart Grids, or the latest renewable energy solutions [7].

The challenges of human capital management begin with the stage of forming interest in the academic discipline itself among students.

Quite often, there is a decrease in the “attractiveness” of the educational component of “Power Supply” compared to other, more “fashionable” or high-paid areas. Students, focusing on the technologies of the future, often perceive this subject as too traditional or difficult, but without a guarantee of high remuneration, preferring the IT component of electricity, automation or management. This greatly reduces the level of motivation of students to study the engineering intricacies of this vital subject in depth.

A key aspect of human capital management in the training of specialists in the field of electricity supply is the establishment of effective interaction between the university and the production sector. This is necessary to ensure the relevance of knowledge and practical training of graduates.

Management of interaction between the university and enterprises (production) should cover the following key areas:

1) Actualization of educational programs (content management):

- Joint development of programs – regular involvement of representatives of enterprises (chief engineers, heads of departments) in the formation of educational programs of disciplines (in particular, "Power Supply"). This ensures that the content of the training meets the current needs of the industry, technological trends (Smart Grid, RES, digitalization) and labor market requirements.
- Creation of joint courses (modules) – development and implementation of specialized training modules taught by production practitioners.

2) Organization of practical training (experience management):

- Internship and internship bases – signing long-term agreements with enterprises (energy companies, industrial enterprises, design organizations) to provide students with quality places for internships. Students must work with real, modern equipment [15].
- Dual education is the introduction of elements of dual education, when theoretical training at the university alternates with paid practical work in production under the guidance of a mentor.
- Implementation of diploma projects – encouragement of the implementation of diploma (qualification) and term papers on real technical tasks of enterprises.

3) Provision of material and technical base (resource management):

- Joint laboratories (centers) – creation of joint educational and research laboratories based on the university, equipped with the support of enterprises. This allows students to work with the same technologies as in production [20].
- Provision of equipment and specialized software – involvement of enterprises in providing the university with decommissioned, but still relevant equipment (transformers, switching equipment) and licensed software.

4) Support for teaching staff (personnel management):

- Internship of scientific and pedagogical workers is the organization of regular internships of teachers in production (every 3-5 years) to update their knowledge and practical skills.
- Involvement of practitioners in teaching – invitation of practicing engineers, supervisors and experienced specialists to conduct guest lectures, master classes and management of diploma theses. This helps to at least partially compensate for the outflow of experienced personnel from universities.

5) Collaborative research and innovation (development management):

- R&D activities are cooperation in the implementation of joint research and innovation projects aimed at solving urgent problems of energy companies (for example, improving energy efficiency, equipment diagnostics).
- Organization of joint events – holding joint conferences, seminars and hackathons, which stimulates the mutual exchange of knowledge between students, scientific and pedagogical workers and energy engineers in production.

Effective management of this interaction transforms the training process from purely academic to applied, which provides the industry with specialists ready to work.

6. Conclusions

The processes of decentralization and green transition create new managerial imperatives for universities. To ensure national energy sustainability, it is necessary to move from an outdated academic model to a flexible, practice-oriented system of training specialists.

The content of education requires radical actualization. Curricula are critically lagging behind the integration of distributed generation, Smart Grids, and energy storage. Content management should focus on interdisciplinary modules that combine the key knowledge of the discipline "Electricity Supply" with digital technologies and the economics of renewable sources, preparing specialists to work with adaptive and intelligent networks.

Effective resource management involves moving away from limited internal funding to a collaborative and co-investment strategy. Universities should create joint training and research centers and digital simulation sites with production, providing students with access to modern equipment and licensed software.

The field of human capital is a high-risk area. There is an outflow of practicing teachers who are able to teach relevant material in the discipline "Power Supply" to a higher-paid manufacturing sector and a decrease in the prestige of classical engineering among applicants. Management decisions should provide systematic support for teachers' internships in production and purposeful formation of the image of the discipline "Power Supply" as a key, high-tech block for the future energy sector.

Interaction with production is one of the most effective tools for overcoming challenges. It is necessary to move from formal practice to a model of strategic partnership, which includes: a dual approach to training, active involvement of practicing engineers in teaching specific sections of "Power Supply" and joint research work to solve urgent industry problems of the "green" transition.

High-quality training of electricity supply specialists in the context of decentralization is a matter of national security. The managerial aspects of higher education in this area require comprehensive and systemic solutions focused on deep integration with the needs of the energy sector of Ukraine.

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