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System Aspects of Scientific Researches in Power Engineering

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Abstract
Methodology of systems analysis has received wide practical application as widespread universal methodology of scientific researches. Its effectiveness is shown in both researches and elaboration of complex objects with large number of connections between structural components, and in process of student learning, especially in higher education system. Features of use of basic principles of system analysis for decision of problems of modeling of objects of power engineering, in particular their representation in disciplines of electric specialties are considered. Examples of definition of categories of systems theory (super system, system, subsystem, element, process) which improve students' understanding of essence of modeling in electro energetic are represented. Importance of consideration of relationships between components of system model, possibility of change of efficiency of functioning of system, and even its functions, when change both components of system and relationships between them are explained. Definition of components of model of type "black box" and sequence of complication of structural model are considered on example of system "Power engineering". Possible variants of structural models at steps of detailing, their dependence on purpose of research or discipline studied by students are shown.

INTRODUCTION

Systems approach as research methodology has become widespread in almost all areas of modern science and technology, especially in development, improvement or research of complex systems. Systems theory and system analysis are included in curriculums of many specialties [1–3], much attention is paid to use of system analysis as methodological basis for pedagogy of preschool [4], secondary [5, 6] and higher [1, 2] education.

Despite number of scientific and educational publications, many issues on methodology of system approach are still debatable: definitions of categories and concepts of systems theory, principles of systems analysis, features of systems modeling are defined more exactly. This state of problem is objective in nature and is explained by universality of system analysis methodology. The majority of published work is devoted to peculiarities of its application in various fields of knowledge: pedagogy [7], sociology [8, 9], agriculture [10], medicine [11] and many others.

The effectiveness of the systems approach is evident in the effectiveness of research, such as environmental or climatic problems of a planetary nature, in the design of modern technical systems with elements of artificial intelligence [9, 12], analysis of safety factors [13, 14], in higher education – in teaching almost any discipline.

Typical example of complex system is such branch of economy of any country as electro energetics. Application of methodology of system approach allows to find optimum and effective decisions of difficult problems when solving problems of development planning [15], innovative technologies [16], design [17, 18], research of processes both in separate components [19–21], and in electro energetics as whole [22, 23]. Teaching disciplines of electro energetics profile in universities on basis of methodology of system analysis for long time contributes to better understanding and assimilation of material of disciplines of curriculums by students.

The purpose of this work is to consider the systemic aspects of research in the power industry and the application of a systems approach in the teaching of disciplines of the power industry.

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MAIN CATEGORIES OF SYSTEMS THEORY

Among the categories of systems theory [24–27], we distinguish the following: system, subsystem, element, supersystem, process. There is currently no general accepted definition of these concepts. We give definitions [28, 28], which, in the opinion of the authors, sufficiently allow to describe the processes in the electric power industry, the electric power industry itself, as a system, and its components.

We consider system as set of material or abstract objects, phenomena, processes isolated from environment, which have certain set of properties, and interaction of which ensures achievement of certain function over certain period of time.

Considering the structure of the system in its composition, we distinguish subsystems and elements. A subsystem is a set of components selected within the system, which have a certain set of properties, and the interaction of which ensures the implementation of some component function of the system. This function is considered as a subfunction (component) of the system function. An element (system, subsystem) is characterized by the fact that in the study it is not divided into components, and its interaction with other elements or subsystems of the system provides the implementation of some subfunction of the overall function of the system.

The interaction of the components of the system is realized in some processes, the course of which ensures the implementation of subfunctions and functions of the system as a whole. That is, a process is a set of successive actions (changes in the state or values of the parameters of the components of the system) to achieve a certain result (implementation of the system function).

Any system is considered as a component of a larger system – a supersystem. From the point of view of this, in cases when research focuses on the properties of a subsystem, in order to simplify the explanation, we call it a system.

PRINCIPLES OF SYSTEM ANALYSIS

Among the principles of systems analysis [24, 27], consider those that are most often used objects and processes of electric power.

The principle of hierarchy is that the study of complex systems is based on the idea of the hierarchy of their structure. Hierarchy means the arrangement of parts and elements of a whole in the order from highest to lowest and the relationship between these parts and elements. For example, the hierarchy of the control system of technological integration of the integrated energy system in each country has a conceptual significance and affects both the efficiency of the energy industry and the energy security of the country.

The principle of multidimensionality is that any system has a large set of properties, grouped in groups, each of which describes one or another of its features. An objective description of the system requires a study of the maximum number (ideally all) of these groups. Note that the consideration of the number of parts and properties of the system is always limited to the purpose of the study, and in the education system - the work program of a particular discipline. But the set of disciplines in the curriculum of a particular specialty can be considered as the implementation of the principle of multidimensionality.

The principle of integrity is that the system is studied in the unity of the interacting parts. A holistic system discovers properties and modes of action that cannot be explained by a simple summation of the properties and modes of action of its parts. For example, consideration of the power supply system of a certain industrial enterprise in the unity of interaction of its parts (external power supply system, transformer substations, distribution points, distribution network, relay protection and automation systems, etc.) allows to fully ensure reliable power supply of the enterprise.

The principle of maximum efficiency of the system states that there is always a function of the value of the system as a dependence of its efficiency on the conditions of construction and operation, and this function has an extremum. For the power industry, this principle can be considered as a minimum loss and the minimum cost of electricity, provided the reliability of electricity supply [30, 31].

The application of these principles in the consideration of technical objects requires a combination of structural and functional aspects of their study. These aspects are the methodological foundations of the systems approach.

The structural aspect includes solving two interrelated tasks: identifying the components (subsystems, elements) of which the system consists, and determining how these components are interconnected. Here the researcher analyzes the structure of the system and its subsystems.

The functional aspect of the study also has two directions: analysis of the internal functioning, the mechanism of interaction of elements and subsystems within the system under study; analysis of the external functioning of the system, its interaction within the supersystem.

FEATURES OF METHODOLOGY OF SYSTEM ANALYSIS

In the practice of scientific research, the approach to the study of unknown systems, processes and phenomena from simple to complex has traditionally developed. In systems analysis, an approach to the

study of systems is adopted – from complex to simple. Namely, the consideration begins with a generalized model of the system, then considers the most important components of the system and the relationships between them. Then carry out the detailing of components and connections, which "immerses" in the depth of the study of the problem. The "depth" of the study (the degree of division of the system into components) is determined by the purpose of the study, that is, the researcher himself.

The most generalized model in systems theory is the "black box" model (Fig. 1) [24, 28]. The main components of this model are: supersystem, system boundaries, input flows, output flows, interference. Assembly of a model of the "black box" type begins with the allocation within a system of the object of study, the establishment of its boundaries. The object of study and its model are considered as a system, and the system within which the object operates is considered as a supersystem for the system under study. In the supersystem, the input streams of the system under study and its output streams are determined. Interference is also determined - factors that under certain conditions significantly affect the performance of the system (output flows).
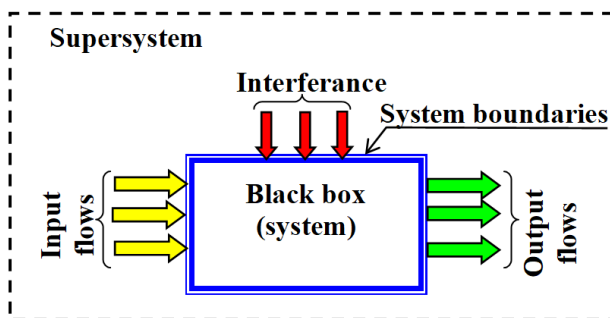

Figure 1. "Black box" system model

So, the "black box" model is a universal model, which, at the first stage of research, allows you to start considering any system [32–35]. At the next stages, depending on the purpose of the study, it acquires the necessary detail and binding to a specific subject area.

Detailing the model of the "black box" is to determine its structure. Structure in systems analysis means the many components that make up a system and the many relationships between these components. If we consider the components without connections between them, then this is a model of the composition of the system, which is the initial stage of the study of the system. The next mandatory step is to study the relationships between the components of the system, that is, to consider its structural model.

Connections play an important role in the structure of the system. With the unchanged composition of the elements, different systems can be obtained

with different properties, or even with different laws of functioning.

Thus, the main inherent in any structure is the elemental composition, the presence of connections, invariance (immutability) in time. This property allows you to distinguish between the concepts of system and structure (object and its model). The structure is part of the system. It is important to clearly indicate which part, which properties and features of the system are structured (considered, investigated), and which are not. The answers to these questions, as already noted, depend on the objectives of the study of the system.

Depending on the goals of the researcher, different, time-invariant properties of the system are of interest. It follows from this that different structures (models) can be built for one system.

The implementation of a systematic approach from simple to complex is traditionally used in combination with the principle of hierarchy when teaching disciplines of the specialty "Power engineering", "Electrical Engineering and Electromechanics". The study of such disciplines as "Electrical systems and networks", "Automated dispatch control systems", etc., requires a model representation of the electric power industry as a system. Consider the implementation of the principle of hierarchy using the example of the sequence of constructing a structural model of the electric power industry

MODEL REPRESENTATION OF POWER ENGINEERING AS SYSTEM

Let us consider examples of conceptual issues of a systems approach to the consideration of electric power using IDEF [27] modeling methodology.

The first step is level A0. Consider a generalized model of the system "Energy in Ukraine" type "black box" (Fig. 1). We specify elements of this model.

System boundaries. In our case, this is the territory of Ukraine, where all the components (subsystems and elements) of the system are located. Historically, it so happened that within the boundaries of the territory of each country is its "Energy in Ukraine" system, the main task of which is to provide electricity to consumers on the territory of this country.

Supersystem. What to include in the supersystem depends on the objectives of the study. If this is an examination of the processes of controlling the flows of electricity, then the supersystems include the power systems of neighboring countries with which there are power flows. Power flows with neighboring countries are an important factor in the management of the interconnected power system. Consideration of the issues of reliability of the power system requires taking into account climatic factors. In this case, we refer the climate of Ukraine to

the supersystem. Other approaches to the consideration of the supersystem are also possible.

Input flows. For the "Energy in Ukraine" system, these are energy resources (nuclear fuel, gas, fuel oil, coal, water resources, wind energy, solar energy, etc.) from which electrical energy is produced.

Output flows. For the "Energy in Ukraine" system, this is electrical and heat energy at the entrances to its consumers. Output flows also include negative factors in the functioning of the electric power industry, for example, factors affecting the environment.

The final element of the "black box" model is interference – factors that lead to disruptions in the normal functioning of the system. In our case, the interference can be attributed to natural factors of the external environment (ice, thunderstorm activity, etc.), factors of a subjective-human nature, political factors, etc. Specification of the consideration of interference depends on the task of studying the model of the system.

The second step is detailing the generalized model of the A0 level, highlighting its main subsystems and elucidating the connections between them. The level of detail in this and all subsequent steps depends on the purpose of the system study. Thus, examining the main function of the "Energy in Ukraine" system, which is to provide consumers with electrical energy, it is possible to draw up a structural model with four subsystems: A1 is a "Generation of electric power" subsystem; A2 is a "Transportation of electric power" subsystem; A3 is a "Distridution of electric power" subsystem and A4 is a "Utilization of electric power" subsystem (Fig. 2).
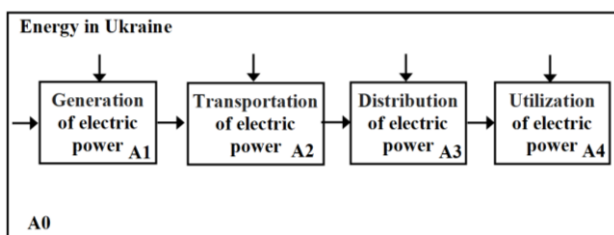

Figure 2. Detailing of model of system "Energy in Ukraine"

The third step of detailing is the consideration of the structures of the A1–A4 subsystems, which were identified as part of the system at the A0 level.

For the subsystem "Generation of electric power", you can create structural models shown in Fig. 3*a* and Fig. 3*b*. According to the first option (Fig. 3*a*), the "Generation of electric power" system is investigated as part of two subsystems – "System power stations" and "Local power stations". This approach makes sense in the case of investigating the operational dispatch control of the mode of the interconnected power system. Power plants of sys-

tem importance ensure the formation of the mode of the interconnected power system in terms of voltage and power balances. Local power plants do not have a significant impact on the regime of the interconnected power system.
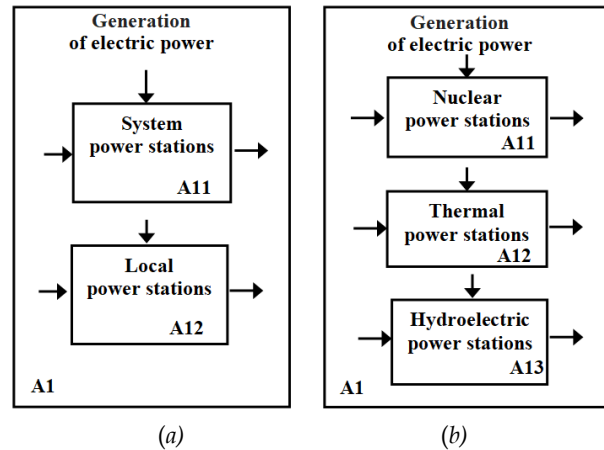

Figure 3. Options of detailing of system "Generation of electric power"

The second variant of the division (Fig. 3*b*) according to the types of power plants (nuclear, thermal, hydraulic, etc.) makes sense in the case of studying the features of the technology for the production of electrical energy.

The electricity transportation system (subsystem A2 in Fig. 2) can be presented with various structural models. For example, the division into regional energy systems (ES) in Ukraine: Western ES (A21), South-Western ES (A22), Central ES (A23) and other energy systems. The second option is the division of the "Transportation electric power" system into components according to voltage levels: at a voltage of 750 kV (A21), at a voltage of 500 kV (A22), at a voltage of 330 kV (A23), etc.

The electricity distribution system (subsystem A3 in Fig. 2) can be divided into components based on local energy companies (in Ukraine: Lvovoblenergo, Kievoblenergo, Kharkovoblenergo and others) or on the basis of voltage class (110 kV, 35 kV, 10 kV, 0.4 kV).

The system of electricity consumption (subsystem A4 in Fig. 2) is studied by students as a separate discipline "Consumers of electrical energy". In its structure, there are characteristic groups of electrical receivers (cities, city districts, transport, industrial enterprises, etc.), which, in turn, consist of electrical receivers (electric motors, stoves, lighting, etc.).

As a result of detailing the structural model of the first level (Fig. 2), it is possible to obtain a variant of the structural model of the "Energy in Ukraine" system of the second level, shown in Fig. 4. Note that this model does not take into account the links on electricity flows with neighboring countries.
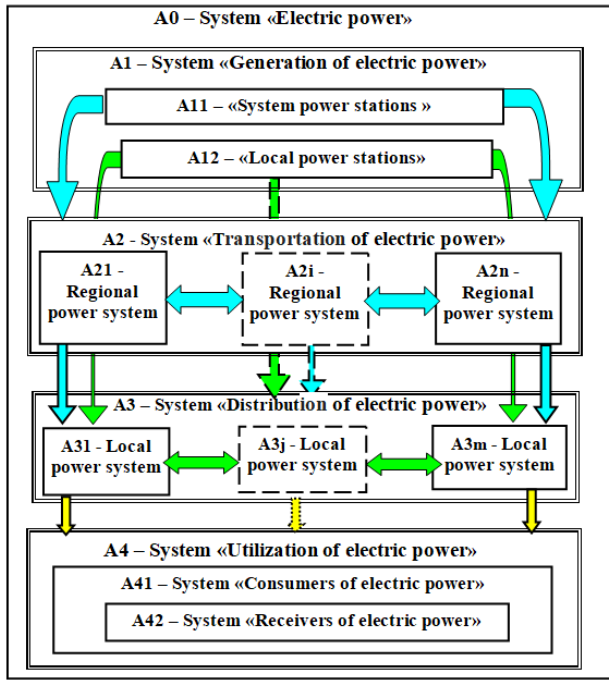
Figure 4. Variant of structural model of system "Electric power" [28]

Note that the structural model of electric power shown in Fig. 4 is not its only model. Depending on the specific discipline of the curriculum of the specialty, and apparently from the topic of the same discipline, the model may have a different composition and other connections between the components.

The methodology of system analysis, in addition to the graphical one, provides for other forms of presenting the description of systems. For example, considering the relay protection function as a system, its structure is presented as sub-functions by enumerating the types of relay protection. The structural model of the "Power Transformer Relay Protection" system can look like this.

Function → "Power transformer relay protection" system.

Sub-functions (constituent functions) → subsystems:

- "Protection against multiphase faults in windings and at their terminals";
- "Protection against internal damage (turn short circuits in windings and "steel fire"of the magnetic circuit)";
- "Protection against single-phase earth faults";
- "Protection against overcurrents in windings caused by external short circuits";
- "Protection against overcurrents in windings due to overload";
- "Protection against low oil level".

For a specific power transformer at a certain substation, this structural model will be presented as a list of specific types of protection, and in practice, as an electrical relay protection circuit for this trans-

former with a description of the types of all components and their operation.

Approaches to the analysis of electrical systems and the use of one or another principle of systems analysis depend on the discipline studied by the student. So, for example, the principle of maximum system efficiency in the course "Electrical systems and networks" is considered primarily as a maximum with the electricity produced by power plants and received by consumers of electrical energy. And this presupposes the solution of the problem of obtaining minimum losses of electricity in the elements of electrical networks. And in the discipline "Reliability of electrical networks" maximum efficiency is considered as the maximum, economically feasible uninterrupted transmission of electricity to consumers.

Let's consider some features of the systematic approach to teaching the discipline "Consumers of electrical energy". The first priority is to consider the concepts of "electrical receiver" and "electrical consumers", the definition of which is given in the PUE [28].

First, we consider the definition of the concept of an electrical receiver - an electrical device "designed to convert electrical energy into another type of energy" [28] and build its model of the "black box" type (Fig. 5). A generalized, model representation of an electric receiver allows one to abstract from its specific type and focus on: the value of the parameters of the incoming flow (nominal voltage and power), the value of the internal parameters of the electric receiver, in particular, the efficiency η, energy at the input of the electrical receiver at its efficiency.
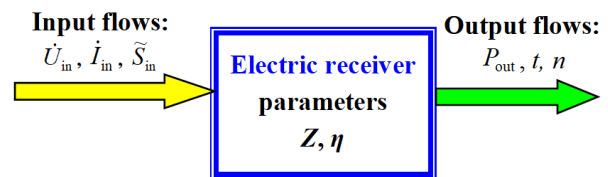

Figure 5. "Black box" type electric receiver model [28]

At the same time, the attention of students is drawn to the fact that the receiver of electrical energy itself (its parameters and operating mode) affect the parameters of the power supply system. For this, a model of the interaction of the power supply system with an electrical receiver is being built (Fig. 6). In the future, when studying specific groups of power consumers, this model makes it possible to find out the parameters of the power receiver worsen the power quality indicators in the power supply system and how the mode of its operation affects the mode of operation of the power supply system.
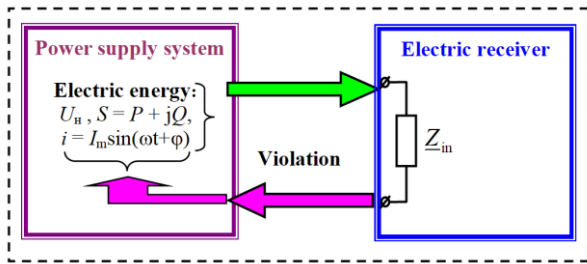
Figure 6. Model of interaction of electric receiver and power supply system [28]

After shifting the concept of "electrical consumer" is considered as a set of electrical consumers "located on a certain territory and united by a common technological process" [28]. For example, the procedure for constructing a model "Industrial enterprise" is given – a consumer of electrical energy in the following sequence. Some electrical receiver, for example, an asynchronous motor (AM) is considered as an integral part of a lathe, in which there are two asynchronous motors – one main second auxiliary electric drive. The student's attention is drawn to the fact that separately taken AM of the main electric drive, as well as the AM of an auxiliary electric drive, are electrical receivers, and together and the AM as part of a lathe are electrical consumers.

Further enlargement of power consumers, namely a group of lathes at the turning section, create power consumers "Section No. 1". This section, together with other sections, creates the "Mechanical Shop" electrical consumers (Fig. 7). Consideration of all shops creates a system of "power consumers industrial plant" (Fig. 8).
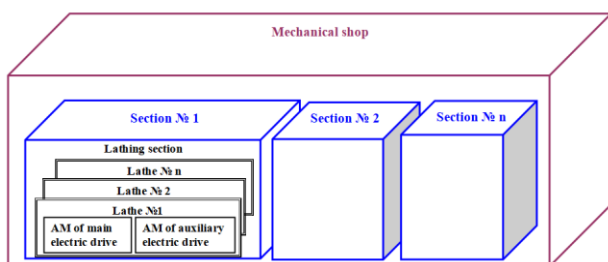

Figure 7. Model of electric consumer "Mechanical shop" [28]
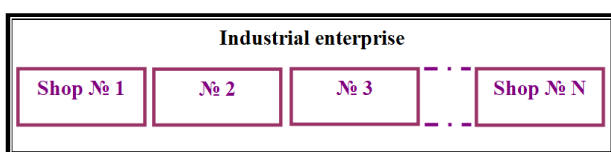

Figure 8. Model of electric consumer "Industrial enterprise" [28]

Such a construction of the consumer model "Industrial enterprise" from a simple "Electricity receiver" to a complex one – the consumer "Industrial enterprise" makes sense for a better understanding of the interaction of the components of the power supply system (Fig. 6), in particular the influence of the consumer on the mode of his power supply system. At the same time, it is clear that the simple sum of the installed capacities of the power consumers of an enterprise differs from the calculated power of the power consumers "enterprise", because it is necessary to take into account the daily schedule of power consumption of each electric receiver at this enterprise. And these charts have disagreements in the time of power consumption.

CONCLUSIONS

The application of the system analysis methodology, in particular the principles of system analysis, in the educational process when teaching disciplines in electric power specialties allows students to focus on the main issues, facilitates understanding the essence of processes in complex, multicomponent electrical systems and devices.

Understanding by students of the systemic aspects of scientific research contributes to the effectiveness of training future researchers and scientists.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

REFERENCES

1. Fiala, V., Freyer, B., Klimek, M., & Fahringer, A. (2018). How do you teach transdisciplinary competences for food and farming systems research? Insights from the course "System Analysis and Scenario Technique". *Open Agriculture, 3*(1), 553-566. https://doi.org/10.1515/opag-2018-0059

2. Li, Q. (2017). Discussion on the teaching of water resources system analysis in 'Outstanding Engineer Education Training Plan'. In *2017 2nd International Conference on Politics, Economics and Law (ICPEL)* (pp. 177–180). Atlantis Press. https://doi.org/10.2991/icpel-17.2017.46

3. Muñoz-Carpio, J.C., Cowling, M., & Birt, J. (2018). Framework to enhance teaching and learning in system analysis and unified modelling language. In *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)* (pp. 91–98). IEEE. https://doi.org/10.1109/TALE.2018.8615284

4. Yaşar, M. (2017). Adaptation of general system theory and structural family therapy aproach to classroom management in early childhood education. *Cukurova University Faculty of Education Journal, 46*(2), 665–696. https://doi.org/10.14812/cuefd.300993

5. Ao, Y., & Li, H. (2020). Internal governance dilemma and rational regression in higher vocational colleges: based on perspective of system theory. In *5th International Conference on Economics, Management, Law and Education (EMLE 2019)* (pp. 1216–1220). Atlantis Press. https://doi.org/10.2991/aebmr.k.191225.241

6. Xiang, H. (2020). Research on fuzzy comprehensive evaluation of university public physical education classroom teaching quality based on grey system theory. *Frontiers in Educational Research, 3*(13), 169–176. https://doi.org/10.25236/FER.2020.031328

7. Barot, T. (2017). Possibilities of process modeling in pedagogical cybernetics based on control-system-theory approaches. In R. Silhavy, R. Senkerik, Z. Kominkova Oplatkova, Z. Prokopova, P. Silhavy (Eds.), *Cybernetics and Mathematics Applications in Intelligent Systems*. AISC, Vol. 574 (pp. 110–119). Springer. https://doi.org/10.1007/978-3-319-57264-2_11

8. Davi, H., Tuffery, L., Garbolino, E., Prévosto, B., & Fady, B. (2020). Using socioeconomic system analysis to define scientific needs: a reverse engineering method applied to the conversion of a coal-fired to a wood biomass power plant. *Ecology and Society, 25*(4), 16. https://doi.org/10.5751/ES-11929-250416

9. Fisogni, P. (2019). Cyber terrorism and self-radicalization – emergent phenomena of onlife age: An essay through the general system theory. *International Journal of Cyber Warfare and Terrorism (IJCWT), 9*(3), 21–35. https://doi.org/10.4018/IJCWT.2019070102

10. Berhanu, Y., Angassa, A., & Aune, J.B. (2021). A system analysis to assess the effect of low-cost agricultural technologies on productivity, income and GHG emissions in mixed farming systems in southern Ethiopia. *Agricultural Systems, 187*, 102988. https://doi.org/10.1016/j.agsy.2020.102988

11. Tramonti, F., Giorgi, F., & Fanali, A. (2019). General system theory as a framework for biopsychosocial research and practice in mental health. *Systems Research and Behavioral Science, 36*(3), 332–341. https://doi.org/10.1002/sres.2593

12. Bakirtzis, G., Simon, B.J., Collins, A.G., Fleming, C.H., & Elks, C.R. (2019). Data-driven vulnerability exploration for design phase system analysis. *IEEE Systems Journal, 14*(4), 4864–4873. https://doi.org/10.1109/JSYST.2019.2940145

13. Jamot, D.G.C., & Park, J.Y. (2019). System theory based hazard analysis for construction site safety: A case study from Cameroon. *Safety Science, 118*, 783–794. https://doi.org/10.1016/j.ssci.2019.06.007

14. Yousefi, A., & Hernandez, M.R. (2019). Using a system theory based method (STAMP) for hazard analysis in process industry. *Journal of Loss Prevention in the Process Industries, 61*, 305–324. https://doi.org/10.1016/j.jlp.2019.06.014

15. Gunkel, P.A., Koduvere, H., Kirkerud, J.G., Fausto, F.J., & Ravn, H. (2020). Modelling transmission systems in energy system analysis: A comparative study. *Journal of Environmental Management, 262*, 110289. https://doi.org/10.1016/j.jenvman.2020.110289

16. Kochański, M., Korczak, K., & Skoczkowski, T. (2020). Technology innovation system analysis of electricity smart metering in the European Union. *Energies, 13*(4), 916. https://doi.org/10.3390/en13040916

17. Loboda, A.V., & Chuikina, A.A. (2020). About the alignment design of heat supply systems on the basis of system analysis. *Russian Journal of Building Construction and Architecture, 3*, 35–45. https://doi.org/10.36622/vstu.2020.47.3.003

18. Shcherbak, I. (2019). Mathematical model of consumer regulators management for alignment of electric load graphs of transformer substation 10/0.4 kV. *Lighting Engineering & Power Engineering, 3*(56), 125–129. https://doi.org/10.33042/2079-424X-2019-3-56-125-129

19. Frivaldsky, M., Piri, M., Spanik, P., Jaros, V., & Kondelova, A. (2017). Peak efficiency and peak power point operation of wireless energy transfer (WET) system — analysis and verification. *Electrical Engineering, 99*(4), 1439–1451. https://doi.org/10.1007/s00202-017-0658-4

20. González-Gil, A., Palacin, R., Batty, P., & Powell, J. P. (2014). A systems approach to reduce urban rail energy consumption. *Energy Conversion and Management, 80*, 509–524. https://doi.org/10.1016/j.enconman.2014.01.060

21. Malyarenko, V., Andreev, S., & Kazarova, I. (2018). Ways of increasing the efficiency of public energy service by means of cogeneration implementation. *Lighting Engineering & Power Engineering, 2*(52), 59–62. https://doi.org/10.33042/2079-424X-2018-2-52-59-62 (in Ukrainian)

22. Kühnbach, M., Guthoff, F., Bekk, A., & Eltrop, L. (2020). Development of scenarios for a multi-model system analysis based on the example of a cellular energy system. *Energies, 13*(4), 773. https://doi.org/10.3390/en13040773

23. Arkhipova, O.V. (2021). Principles of system analysis for sustainable electric power supply to agro-industrial complexes operating in energy isolated territories. *IOP Conference Series: Earth and Environmental Science 723*(5), 052032. https://doi.org/10.1088/1755-1315/723/5/052032

24. von Bertalanffy, L. (2015). *General System Theory: Foundations, Development, Applications*. George Braziller

25. Fröhlich, T. (2019). General system theory (GST) and a non-reductionist concept of elements: Suggesting a corresponding discussion based on Tramonti (2019). *Systems Research and Behavioral Science, 36*(3), 342–345. https://doi.org/10.1002/sres.2592

26. Van Assche, K., Valentinov, V., & Verschraegen, G. (2019). Ludwig von Bertalanffy and his enduring relevance: Celebrating 50 years General System Theory. *Systems Research and Behavioral Science, 36*(3), 251–254. https://doi.org/10.1002/sres.2589

27. Achkasov, A.Y., Lushkin, V.A., Okhrimenko, V.M., & Voronkova, T.B. (2013). *Systems Theory and Systems Analysis*. O. M. Beketov National University of Urban Economy in Kharkiv. https://eprints.kname.edu.ua/38976/ (in Ukrainian)

28. Okhrimenko, V.M. (2019). *Electricity Consumers: tutorial*. O. M. Beketov National University of Urban Economy in Kharkiv. https://doi.org/10.30888/978-966-695-487-2.2019 (in Ukrainian)

29. Ministry of Energy and Coal industry of Ukraine. (2017). Rules of arrangement of electrical equipment.

https://ua.energy/wp-content/uploads/2018/06/PUE.pdf (in Ukrainian)

30. Munasinghe, M. (1981). Optimal electricity supply: reliability, pricing and system planning. *Energy Economics, 3*(3), 140–152. https://doi.org/10.1016/0140-9883(81)90035-9

31. Hamedi, H., & Gandomkar, M. (2012). A straightforward approach to minimizing unsupplied energy and power loss through DG placement and evaluating power quality in relation to load variations over time. *International Journal of Electrical Power & Energy Systems, 35*(1), 93–96. https://doi.org/10.1016/j.ijepes.2011.10.001

32. Bajzek, M., Fritz, J., Hick, H., Maletz, M., Faustmann, C., & Stieglbauer, G. (2020). Model based systems engineering concepts. In H. Hick, K. Küpper, H. Sorger (Eds.), *Systems Engineering for Automotive Power-train Development*. Powertrain (pp. 1–40). Springer https://doi.org/10.1007/978-3-319-68847-3_8-1

33. Kübler, K., Scheifele, S., Scheifele, C., & Riedel, O. (2018). Model-based systems engineering for machine tools and production systems (model-based production engineering). *Procedia Manufacturing, 24*, 216-221. https://doi.org/10.1016/j.promfg.2018.06.036

34. Hick, H., Bajzek, M., & Faustmann, C. (2019). Definition of a system model for model-based development. *SN Applied Sciences, 1*(9), 1074. https://doi.org/10.1007/s42452-019-1069-0

35. Khrutba, V., Anpilova, Y., Lukianova, V., Kotsiuba, I., Kriukovska, L., & Spasichenko, O. (2021). Evaluation of the impact on the environment at building and reconstruction of motorways using the system analysis method. *Environmental Research, Engineering and Management, 77*(1), 85–95. https://doi.org/10.5755/j01.erem.77.1.27887

Системні аспекти наукових досліджень в електроенергетиці

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Анотація. Методологія системного аналізу отримала широке практичне застосування як розповсюджена універсальна методологія наукових досліджень. Її ефективність проявляється як при дослідженнях і розробленнях складних об'єктів з великою кількістю зв'язків між структурними компонентами, так і в процесі навчання студентів, особливо у системі вищої освіти. Розглянуті особливості застосування основних принципів системного аналізу для вирішення завдань моделювання об'єктів електроенергетики, зокрема в дисциплінах електроенергетичних спеціальностей. Надані приклади визначення категорій теорії систем (надсистема, система, підсистема, елемент, процес), які поліпшують розуміння студентами суті моделювання в електроенергетиці. Розглянуто важливість розгляду зв'язків між складовими моделі системи, можливість зміни ефективності функціонування системи, і навіть її функції, при зміні як складових системи, так і зв'язків між ними. На прикладі системи «Електроенергетика» розглянуто визначення складових моделі типу «чорний ящик» та послідовність ускладнення структурної моделі. Показані можливі варіанти структурних моделей на шагах деталізації, їх залежність від мети дослідження або дисципліни, що вивчається студентами.

Ключові слова: електроенергетика, методологія, процес, системний аналіз, структурна модель.

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