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CHALLENGES IN THE SMART GRID MANAGEMENT SYSTEMS: A UNIVERSITY ENERGY EFFICIENCY HUB CASE STUDY

The article attempts to tackle the issues of enhancing the performance of university energy efficiency management systems. An emphasis is put that in modern realia, alternative and renewable energy sources are becoming increasingly important in the electric power sector, thus contributing to environmental protection and enabling active electricity consumers to have their own sources of energy generation. However, it is observed that the relationships between energy generation sources and electricity consumers are complicated by new demands for setting balancing modes due to certain volatility of energy generation by alternative sources as well as the need to connect additional energy storage facilities. To identify opportunities of using Smart Grid technologies to manage the University energy consumption, a power balance equation was used to determine an active power balance between generated power, generation sources and power consumed by electricity consumers. In addition, the indicators of the total active power loss in the electrical network associated with the technological consumption of energy for its transmission was included into this equation. The study presents the results of an in-depth critical analysis on Smart Grid methodology and provides argument for the relevance of using artificial intelligence techniques in Smart Grid management systems of the University energy efficiency hub, along with suggesting a notion of electricity generating consumer in the concept of intelligent networks with two-way flow of energy and information as subsystems of a different nature. It is argued that the developed conceptual model of the electricity generating consumer for multilevel smart grid management systems and their infrastructure within the University energy efficiency hub allows establishing relationships between its structural elements and objects of different character. The findings reveal that the specifics of the developed method in setting priorities and regulatory standards for optimal management by a generating consumer within the University energy efficiency hub is the possibility of its automatic adaptation to changes in the external environment subject to interactions between electricity generating consumers.

Keywords: *University energy efficiency hub; university; Smart Grid; energy consumption.*

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ПРОБЛЕМИ УПРАВЛІННЯ В СИСТЕМАХ SMART GRID УНІВЕРСИТЕТСЬКОГО ХАБА ЕНЕРГОЕФЕКТИВНОСТІ

Статтю присвячено питанням вдосконалення університетських систем управління енергоефективністю. Підкреслюється, що в сучасних умовах все більшого значення в електроенергетиці відіграють альтернативні та відновлювані джерела енергії, які покращують екологічну ситуацію та дозволяють окремим активним електроспоживачам мати власні джерела генерації енергії. Разом з тим, зазначається, що взаємозв'язки між джерелами генерації та електроспоживачами ускладнюються через нові вимоги до балансування режимів, що пояснюється деякою непередбачуваністю генерації енергії альтернативними джерелами, а також необхідністю підключення додаткових об'єктів у вигляді накопичувачів енергії. Для визначення можливості використання Smart Grid-технологій для управління енергоспоживанням університету було застосовано рівняння балансу потужностей, за допомогою якого визначено баланс активної потужності між генерованою потужністю, джерелами генерації і потужністю, що споживається *електроспоживачами. Крім того, до цієї потужності також було додано сумарні втрати активної потужності в електричній мережі, пов'язані з технологічною витратою енергії на її передачу. Виконано критичний аналіз методів розроблення інтелектуальних мереж (Smart Grid) та обґрунтовано необхідність застосування методів штучного інтелекту в управлінні в системах Smart Grid університетського хаба енергоефективності. Запропоновано поняття генеруючого споживача в концепції інтелектуальних мереж із двостороннім потоком енергії та інформації як підсистем різної природи. Доведено, що представлена концептуальна модель генеруючого споживача для багаторівневої організації інтелектуальних мереж Smart Grid та їх інфраструктури в рамках університетського хаба енергоефективності дозволяє встановлювати взаємозв'язки між елементами та об'єктами різної природи. Особливістю розробленого методу розстановки пріоритетів та параметрів правил оптимального управління генеруючим споживачем університетського хаба енергоефективності є можливість автоматичної адаптації під зміни зовнішніх умов та врахування взаємодії генеруючих споживачів між собою.*

Ключові слова: *університетський хаб енергоефективності; університет; Smart Grid; енергоспоживання.*

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ПРОБЛЕМЫ УПРАВЛЕНИЯ В СИСТЕМАХ SMART GRID УНИВЕРСИТЕТСКОГО ХАБА ЭНЕРГОЭФФЕКТИВНОСТИ

Статья посвящена вопросам усовершенствования университетских систем управления энергоэффективностью. Подчёркивается, что в современных условиях все большее значение в электроэнергетике играют альтернативные и возобновляемые источники энергии, которые улучшают экологическую ситуацию и позволяют отдельным активным электропотребителям иметь собственные источники генерации энергии. Вместе с тем отмечается, что взаимосвязи между источниками генерации и электропотребителями усложняются из-за новых требований к балансированию режимов, что объясняется некоторой непредсказуемостью генерации энергии альтернативными источниками, а также необходимостью подключения дополнительных объектов в виде накопителей энергии. Для определения возможности использования Smart Grid-технологий для управления энергопотреблением университета было применено уравнение баланса мощностей, с помощью которого определён баланс активной мощности между генерируемой мощностью, источниками генерации и потребляемой электропотребителями мощностью. Кроме того, к этой мощности были добавлены суммарные потери активной мощности в электрической сети, связанные с технологическим расходом энергии на её передачу. Проведён критический анализ методов разработки интеллектуальных сетей (Smart Grid) и обоснована необходимость применения методов искусственного интеллекта в управлении в системах Smart Grid университетского хаба энергоэффективности. Предложено понятие генерирующего потребителя в концепции интеллектуальных сетей с двусторонним потоком энергии и информации как подсистемы различной природы. Доказано, что представленная концептуальная модель генерирующего потребителя для многоуровневой организации интеллектуальных сетей Smart Grid и их инфраструктуры в рамках университетского хаба энергоэффективности позволяет устанавливать взаимосвязи между элементами и объектами различной природы. Особенностью разработанного метода расстановки приоритетов и параметров правил оптимального управления генерирующим потребителем университетского хаба энергоэффективности *есть возможность автоматической адаптации под изменения внешних условий и взаимодействия генерирующих потребителей между собой.*

Ключевые слова: *университетский хаб энергоэффективности; университет; Smart Grid; энергопотребление.*

Introduction. The term "smart grids" (Smart Grid – Self Monitoring Analysis and Reporting Technology) became common recently (1998), although studies of the possibility of creating and implementing such technologies were conducted in Europe, USA and USSR back in the 1970s (L. Tsoukalas, R. Gao) [1]. Then, from the point of view of I. Gryshchenko, V. Shcherbak, O. Shevchenko, we were talking about self-diagnostics, the main task was to improve the reliability of the equipment and the possibility of its remote control [2; 3]. Currently, the transition from classic power grids to digital is caused by a number of factors. An important issue is global climate change. In addition, according to A. Huang, M. Crow, G. Heydt, J. Zheng, S. Dale [4], increasing fuel costs and the efficiency of renewable energy resources contribute to the development of smart grids. All over the world, networks widely use digital, computer and communication technologies to capture data. Every year these networks are increasingly being upgraded for more economical energy consumption. However, in the networks of the future static consumers are undesirable (V. Shcherbak, L. Ganushchak-Yefimenko, O. Nifatova, P. Dudko, N. Savchuk, I. Solonenchuk), they must be active, and, therefore, the energy supply must dynamically switch between users and local renewable energy sources [6].

Today the term Smart Grid (K. Shaposhnikova, V. Shimov) has acquired a broader meaning and declared itself as a new large-scale direction in the energy sector, allowing, on the one hand, to solve problems related to energy efficiency, reducing energy losses [5]. Every year in the world from 5 to 15% of energy is lost during energy transfer, reduction of resource costs and emissions into the atmosphere. On the other hand, from the point of view of A. Ipakchi, F. Albuyeh) to make the life of modern man more comfortable, for example, with the help of these technologies to control the power supply of the house and electronics in it [7]. It is a new approach to building a power system (G. Mulder, F.D. Ridder, D. Six), meeting such requirements as the ability to self-recovery, resistance to attack, higher quality and reliability of electricity supply, integration of all types of generation and energy storage, motivating consumers to be actively involved in network management [8].

Today this problem, according to K. Ahlert, C.V. Dinther, became urgent for several reasons: firstly, because of the issue of energy efficiency, secondly, a significant reason became the issue of grid wear and tear (problems of energy peaks), thirdly, the reason is that today new opportunities have opened up against the development of modern information technology [9].

The idea of Smart Grid (T.D.H. Cau, R.J. Kaye) currently acts as a concept of intelligent active-adaptive network, which can be described by the following features [10]:

- the saturation of the network with active elements that allow to change the topological parameters of the network;
- a large number of sensors that measure current mode parameters to assess the state of the network in different modes of operation of the power system;
- system of data collection and processing (hardware-software complexes), as well as means of control of active network elements and electrical installations of consumers;
- availability of necessary actuators and mechanisms allowing to change network topological parameters in real-time mode, as well as interact with adjacent power facilities;
- means of automatic evaluation of the current situation and construction of network operation forecasts;
- high performance of the control system and information exchange.

On the basis of the above attributes it is possible to give a fairly clear definition of intelligent network as a set of hardware and software connected to the generating sources and electrical installations of consumers, as well as information and analytical and control systems that provide reliable and quality transfer of electric energy from source to receiver at the right time and in the right quantity [3]. At the same time, new principles, transmission and process control technologies are used. It is supposed to unite at the technological level electric networks, consumers and producers of electricity in a unified automated system. The purpose of this study is to review the main advantages of smart grids over classical power transmission systems, as well as management problems in the university Hub energy efficiency smart grid systems. The study was conducted on the basis of energy consumption data of Kyiv National University of Technologies and Design in 2021.

Matherials and methods. For any electric power system, there is inevitably a tight balance of active power between the power generated by the generation sources and the power consumed by electric consumers. To this power it is necessary to add also the total losses of active power in the electric network, associated with the technological consumption of energy for its transmission.

The power balance equation for the system under consideration can be written in the following form:

$$P_{ex} + P_{aes} \mp P_{scp} = P_{pec} + \sum \Delta P, \tag{1}$$

where P_{ex} – power that can be obtained from an external source;
P_{aes} – alternative energy source;
P_{scp} – storage capacity, battery pack;
P_{pec} – power of the electric consumer;
$\sum \Delta P$ – total active power losses in the network.

The two-way energy flow concept opens up the possibility of obtaining electricity in different ratios from three possible generation sources: the power system, the solar panel, and the storage unit. The cost of these types of energy is different and, in addition, they are determined depending on the two-zone tariff of the cost of electricity of the power system. The efficiency of the decisions made is determined by the optimal ratio of its receipt from the three mentioned types of energy sources at different prices for each hour of the daily load schedule. The problem is an optimization problem with unpredictable, to some extent, power generation of the solar panel and the given restrictions on the possibility to accumulate energy by the storage device.

Results and discussion. In its current form, the smart grid includes the technical basis, control system and transmission protocols from the electrical energy sources to the consumers. The smart grid must also provide real-time information about energy in order to cost-effectively regulate consumption. Realization of key requirements (values) on the basis of the considered basic approaches, according to the ideologists of the Smart Grid concept, can be provided by developing traditional and creating new functional properties of the power system and its elements [1].

In general it can be said that the main goal of Smart Grid is to provide an advantage in six key areas.

The six main advantages of the Smart Grid are:

- reliability, through which it is possible to reduce the cost of outages and power quality disruptions, in addition to reducing the probability of occurrence and consequences of common outages;

- savings – with lower electricity prices compared to classic grids, as well as job creation

- efficiency – with the integration of renewable and alternative energy sources it becomes possible to reduce the cost of electricity production, delivery and consumption;
- environmental friendliness – global climate change is encouraging the use of renewable energy sources as energy resources. This will reduce emissions compared to the public power grid and increase the efficiency of energy production, delivery and consumption;
- protection, which is achieved by reducing the likelihood and consequences of man-made accidents and natural disasters;
- safety by reducing the risks inherent in the excited electric system, as well as reducing the time of exposure to these hazards.

The smart power system concept has the following goals:

- providing consumers with the ability to automatically manage their use of electricity and minimize their costs of paying for electricity;
- self-recovery of the system in the event of an accident;
- use of high-quality energy resources, including renewable ones;
- improving the quality of electricity and reliability of electricity supply [3].

The smart grid must have high efficiency, and for this to combine several technologies, including means of communication, power electronics and control systems. The characteristics of the smart grid exposed to external influences, together with the technologies required to build smart grids, give reason to conduct research in the field of communications, power electronics and control systems, and can be considered for future research work. As an example, there has been a great deal of recent interest in the potential for using renewable energy in the smart grid in conjunction with high-efficiency converters and control systems to improve reliability and reduce carbon emissions at minimal cost (Table 1).

Table 1

The effect of the implementation of the power system based on the concept of Smart Grid University

Parameters	Baseline	Energy system based on the Smart Grid	Ratio of Smart Grid indicators to baseline, %
Electricity consumption (mln kWh)	3,800	1,900	50, decline
Energy intensity of energy consumption (kWh/year)	0,41	0,20	29, decline
Decrease in peak demand (%)	6	25	66, rise
Level of productivity growth (%/year)	2,9	3,2	28, rise
Real power consumption (mln UAH)	2,2	1,3	59, rise
Size of economic damage to business	100	20	90, decline

Research by EPRI [4] shows that transforming today's energy system into an energy system based on the Smart Grid concept results in numerous effects. EPRI estimates 1.8 bln USD in additional revenue for electric grid companies by 2020 due to a significantly more efficient and reliable grid [4].

Renewable energy systems offer economic and environmental advantages in energy production over conventional solid fuel systems. In addition, the use of renewable energy sources implies the availability of clean and reliable energy sources that can be used in rural areas or other locations far away from power plants. The main result in converting energy into electricity depends on power electronics devices and to a large extent on converters, because the load on the grid is mostly variable. Currently, research is being done precisely to improve the performance of inverters. To provide power conversion for solar installations, inverters of various topologies are needed. Moreover, an inverter as a device requires a controller configuration to control switching with greater efficiency. In general, both the inverter and the controller must operate in a way that meets the supply and demand requirements [5].

When building solar and wind systems, special attention is paid to the construction of the maximum power point tracking algorithm. Since power generation based on solar and wind energy depends on weather conditions, it is natural that they need an energy storage device, which is used as a reserve to maintain the required power in the grid. In addition, it is profitable to store energy and direct it to the grid during periods of surplus energy with low energy production and high demand. An efficient and compact way to store energy is to convert it into fuel to store surplus energy. To maximize efficiency and control both the production and consumption of stored energy, electronic converters with bi-directional energy exchange capability should be used. Hydrogen can be used as the fuel cell. The use of a bidirectional inverter allows the highest possible efficiency and control of hydrogen production and consumption. The inverter also allows active energy to be drawn from the grid when it is produced in excess, supplying the DC electrolyzer to produce hydrogen. Other work on energy storage with inverters seeks to combine wind, photovoltaic and fuel plants to maximize energy output and reduce fluctuations in power output for off-grid plants. The proposed hybrid system is then connected to the grid using an inverter as a distributed generation system to relieve the load on the grid and act as a continuous power source when the unconventional energy grid is down. Over the hybrid system, control is performed to reach the maximum power point of the wind and photovoltaic systems, and to ensure the power quality of the electricity fed into the grid from the inverter [6].

An inverter is a powerful electronic device that performs conversion, so it needs a powerful controller. Many types of controllers, some types of digital control, can be studied in the current literature. A critical parameter of inverter controllers is performance, which is determined by the following criteria:

- signal output voltage with low harmonic distortion for linear and nonlinear loads;
- fast response to the change of load;
- low static error. It is possible to use fuzzy control with a variable structure applied to the inverter. Variable control structure is a reliable control method for handling nonlinear systems with changing parameters and external disturbances. It is possible to use neural networks, which are used in the modeling and control of renewable energy systems [2], to track the maximum power point.

Conclusion. There are many challenges in Smart Grid systems, the main ones being information security issues, implementation issues, and automation control issues. The task of automation systems in Smart Grid systems is to maintain system stability when various renewable energy sources are interconnected, and to manage these sources in such a way as to satisfy consumer demands. Bringing in residential customers will allow demand management to reduce peak load, thereby reducing required capacity and cost, as well as increasing efficiency.

It should be noted that the power generated by wind farms, solar power plants, cogeneration plants and other alternative energy sources is not a constant value and depends on natural conditions – wind availability, solar radiation activity, etc. In this case, such instability of generation by renewable energy sources makes its negative adjustments to the stable operation of the power system. The classical principle of organizing the management of electric power systems is not suitable for electric power systems with a large share of renewable energy sources. Smart Grid system implies the use of the latest technologies and algorithms in the process of organization and management, such as virtual power plants, FACTS-systems, phasor, or PMU (Phasor Measurement Unit), direct current inserts (HDVC), various types of energy storage devices, etc. Classic condensing thermal power plants and combined heat and power plants are envisioned as the basic power sources (base power plants) [4].

To summarize, let us distinguish such problems:

- The operation of renewable energy sources (wind and solar) is conditioned by weather and climatic conditions rather than by the needs of users, which makes the management and distribution of electricity even more complex. As a consequence, grid stability in terms of voltage and frequency is affected;

- Thermal power plants, which have to operate at maximum full load, also face problems. Nevertheless, given changes in demand and power generation from solar and wind, plants must adjust their power production quite frequently. This leads to productivity losses and equipment wear and tear.

References

1. Abu-Rayash, A., Dincer, I. (2020). Analysis of the electricity demand trends amidst the COVID-19 coronavirus pandemic. *Energy Res. Soc. Sci.,* 68: 101682.

2. Di Stefano, J. (2000). Energy efficiency and the environment: the potential for energy efficient lighting to save energy and reduce carbon dioxide emissions at Melbourne University, Australia. *Energy,* 25(9): 823–839.

3. Ganushchak-Efimenko, L., Shcherbak, V., Nifatova, O. (2018). Assessing the effects of socially responsible strategic partnerships on building brand equity of integrated business structures in Ukraine. *Oeconomia Copernicana*, 9(4): 715–730.

4. García, S., Parejo, A., Personal, E., Ignacio Guerrero, J., Biscarri, F., León, C. (2021). A retrospective analysis of the impact of the COVID-19 restrictions on energy consumption at a disaggregated level. *Appl. Energy*, 287: 116547.

5. Gryshchenko, I., Shcherbak, V., Shevchenko, O. (2017). A procedure for optimization of energy saving at higher educational institutions. *East.-Eur. J. Enterp. Technol.,* 6(3/90): 65–75.

6. Kaplun, V., Shcherbak, V. (2016). Multifactor analysis of university buildings' energy efficiency. *Actual Probl. Econ.,* 12(186): 349–359.

7. Liu, J., Yao, Q., Hu, Y. (2019). Model predictive control for load frequency of hybrid power system with wind power and thermal power. *Energy,* 172: 555–565.

8. Nayak, J., Mishra, M., Naik, B., Swapnarekha, H., Cengiz, K., Shanmuganathan, V. (2021). An impact study of COVID-19 on six different industries:

Література

1. Abu-Rayash A., Dincer I. Analysis of the electricity demand trends amidst the COVID-19 coronavirus pandemic. *Energy Res. Soc. Sci.* 2020. Iss. 68. Article 101682.

2. Di Stefano J. Energy efficiency and the environment: the potential for energy efficient lighting to save energy and reduce carbon dioxide emissions at Melbourne University, Australia. *Energy.* 2000. No. 25(9). P. 823–839.

3. Ganushchak-Efimenko L., Shcherbak V., Nifatova O. Assessing the effects of socially responsible strategic partnerships on building brand equity of integrated business structures in Ukraine. *Oeconomia Copernicana*. 2018. No. 9(4). P. 715–730.

4. García S., Parejo A., Personal E., Ignacio Guerrero J., Biscarri F., León C. A retrospective analysis of the impact of the COVID-19 restrictions on energy consumption at a disaggregated level. *Appl. Energy*. 2021. No. 287. Article 116547.

5. Gryshchenko I., Shcherbak V., Shevchenko O. A procedure for optimization of energy saving at higher educational institutions. *East.-Eur. J. Enterp. Technol.* 2017. No. 6(3/90). P. 65–75.

6. Kaplun V., Shcherbak V. Multifactor analysis of university buildings' energy efficiency. *Actual Probl. Econ.* 2016. No. 12 (186). P. 349–359.

7. Liu J., Yao Q., Hu Y. Model predictive control for load frequency of hybrid power system with wind power and thermal power. *Energy*. 2019. No. 172. P. 555–565.

8. Nayak J., Mishra M., Naik B., Swapnarekha H., Cengiz K., Shanmuganathan V. An impact study of

Automobile, energy and power, agriculture, education, travel and tourism and consumer electronics. *Expert Syst.,* 10.1111/exsy.12677: 1–32.

9. Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M., Agha, R. (2020). The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *Int. J. Surg.,* 78: 185–193.

10. Shaposhnikova, K., Shimov, V. (2016). ISO 50001-Energy management system. The concept implementation of energy management systems. *Sci. Soc.,* 3–2: 63–68.

11. Shcherbak, V., Ganushchak-Yefimenko, L., Nifatova, O., Dudko, P., Savchuk, N., Solonenchuk, I. (2019). Application of international energy efficiency standards for energy auditing in a University buildings. *Global Journal of Environmental Science and Management,* 5(4): 501–514. doi: 10.22034/GJESM.2019.04.09.

12. Shcherbak, V., Gryshchenko, I., Ganushchak-Yefimenko, L., Nifatova, O., Tkachuk, V., Kostiuk, T., Hotra, V. (2021). Using a sharing-platform to prevent a new outbreak of COVID-19 pandemic in rural areas. *Global Journal of Environmental Science and Management,* 7(2): 155–170. doi: 10.22034/gjesm.2021.02.01.

13. Vieira, E., dos Santos, B., Zampieri, N., da Costa, S., de Lima, E. (2020). Application of the Proknow-C methodology in the search for literature about energy management audit based on international standards. In: Thomé, A., Barbastefano, R., Scavarda, L., dos Reis, J., Amorim, M. (eds.). Industrial engineering and operations management. *IJCIEOM 2020. Springer Proc. Math. Stat.,* 337: 463–475.

14. Wang, Q., Zhang, F. (2021). What does the China's economic recovery after COVID-19 pandemic mean for the economic growth and energy consumption of other countries? *J. Cleaner Prod.,* 295: 126265.

COVID-19 on six different industries: Automobile, energy and power, agriculture, education, travel and tourism and consumer electronics. *Expert Syst.* 2021. 10.1111/exsy.12677: 1–32.

9. Nicola M., Alsafi Z., Sohrabi C., Kerwan A., Al-Jabir A., Iosifidis C., Agha M., Agha R. The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *Int. J. Surg.* 2020. No. 78. P. 185–193.

10. Shaposhnikova K., Shimov V. ISO 50001-Energy management system. The concept implementation of energy management systems. *Sci. Soc.* 2016. No. 3–2. P. 63–68.

11. Shcherbak V., Ganushchak-Yefimenko L., Nifatova O., Dudko P., Savchuk N., Solonenchuk I. Application of international energy efficiency standards for energy auditing in a University buildings. *Global Journal of Environmental Science and Management.* 2019. No. 5 (4). P. 501–514. doi: 10.22034/GJESM.2019.04.09.

12. Shcherbak V., Gryshchenko I., Ganushchak-Yefimenko L., Nifatova O., Tkachuk V., Kostiuk T., Hotra V. Using a sharing-platform to prevent a new outbreak of COVID-19 pandemic in rural areas. *Global Journal of Environmental Science and Management*. 2021. No. 7 (2). P. 155–170. doi: 10.22034/gjesm.2021.02.01.

13. Vieira E., dos Santos B., Zampieri N., da Costa S., de Lima E. Application of the Proknow-C methodology in the search for literature about energy management audit based on international standards. In: Thomé, A., Barbastefano, R., Scavarda, L., dos Reis, J., Amorim, M. (eds.). *Industrial engineering and operations management. IJCIEOM 2020. Springer Proc. Math. Stat.* 2020. No. 337. P. 463–475.

14. Wang Q., Zhang F. What does the China's economic recovery after COVID-19 pandemic mean for the economic growth and energy consumption of other countries? *J. Cleaner Prod.* 2021. No. 295. Article 126265.

15. Werth, A., Gravino, P., Prevedello, G. (2021). Impact analysis of COVID-19 responses on energy grid dynamics in Europe. *Appl. Energy,* 281(116045): 1–24.

16. Xing, X., Yan, Y., Zhang, H., Long, Y., Wang, Y., Liang, Y. (2019). Optimal design of distributed energy systems for industrial parks under gas shortage based on augmented ε-constraint method. *J. Cleaner Prod.,* 218: 782–795.

17. Zhong, H., Tan, Z., He, Y., Xie, L., Kang, C. (2020). Implications of COVID-19 for the electricity industry: A comprehensive review. *CSEE J. Power Energy Syst.,* 6(3): 489–495.

15. Werth A., Gravino P., Prevedello G. Impact analysis of COVID-19 responses on energy grid dynamics in Europe. *Appl. Energy.* 2021. No. 281 (116045). P. 1–24.

16. Xing X., Yan Y., Zhang H., Long Y., Wang Y., Liang Y. Optimal design of distributed energy systems for industrial parks under gas shortage based on augmented ε-constraint method. *J. Cleaner Prod.* 2019. No. 218. P. 782–795.

17. Zhong H., Tan Z., He Y., Xie L., Kang C. Implications of COVID-19 for the electricity industry: A comprehensive review. *CSEE J. Power Energy Syst.* 2020. No. 6 (3). P. 489–495.