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SMART GRID ENERGY CONSERVATION MANAGEMENT BASED ON THE UNIVERSITY'S ENERGY INNOVATION HUB OF KNOWLEDGE

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BACKGROUND AND OBJECTIVES. Due to increasing energy costs, as well as strict environmental regulations, there is a growing need for greater resource efficiency, which makes energy-efficient solutions necessary. Thus, the importance of innovations based on technologies designed to save energy, such as the Smart Grid, is increasing. Smart Grid is not just a compilation of smart meters or other electrical devices, it is a series of technologies, a concept of a fully integrated, self-regulating and self-healing power grid, which has a network topology and includes all sources of generation, transmission and distribution, managed by a single network of information and control devices and systems.

METHODS. As the main method used was the calculation of the synthetic balance of savings from the use of different types of energy resources by the university after the implementation of the application Smart Grid-energy conservation management on the basis of the university energy-innovation Hub of knowledge.

FINDINGS. A mechanism for the implementation of the Smart Grid energy-saving management application on the basis of the university energy-innovation Knowledge Hub is proposed. Smart Grid is designed to provide real-time data on the almost instantaneous balance of energy supply and demand. To ensure grid reliability by reducing peak demands and improving energy efficiency, Smart Grid data management is an affordable and effective tool for data analysis and decision making.

CONCLUSION. The results of calculation of the predicted effect of the Smart Grid application implementation for the 4th building of Kyiv National University of Technologies and Design proved that the reduction of installed capacity as a result of the project was 80.5%, i.e. a 1% reduction in capacity creates an economic effect of 0.58% of the costs associated with modernization. Given the current level of electricity consumption, we can predict a potential reduction of 951 thousand UAH per year or almost 50% of the cost of electricity consumed in 2020.

KEYWORDS: Smart Grid energy conservation management; Energy Efficiency Knowledge HUB; University.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
16	1	2

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SMART GRID-УПРАВЛІННЯ ЕНЕРГОЗБЕРЕЖЕННЯМ НА БАЗІ УНІВЕРСИТЕТСЬКОГО ЕНЕРГОІННОВАЦІЙНОГО ХАБА ЗНАНЬ

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ПОСТАНОВКА ПРОБЛЕМИ ТА ЗАВДАННЯ. У зв'язку зі зростаючими енерговитратами, а також суворими екологічними нормами, зростає потреба у підвищенні ефективності використання ресурсів, що унеможливлює енергоефективні рішення. Таким чином, збільшується значущість інновацій, що базуються на технологіях, призначених для енергозбереження, таких як Smart Grid. Smart Grid - це не просто компіляція інтелектуальних лічильників або інших електричних пристроїв, це ряд технологій, концепція повністю інтегрованої, саморегульованої та самовідновлюваної мережі електроживлення, яка має топологію мережі і включає всі джерела генерації, передачі та розподілу, керовану єдиною мережею інформаційних та керуючих пристроїв та систем.

МЕТОДИ. Як основний метод використано розрахунок синтетичного балансу економії від використання різних видів енергоресурсів університетом після впровадження програми Smart Grid-управління енергозбереженням на базі університетського енергоінноваційного Хаба знань.

РЕЗУЛЬТАТИ. Запропоновано механізм імплементації програми Smart Grid-управління енергозбереженням на базі університетського енергоінноваційного Хаба знань. Smart Grid призначена для надання даних у режимі реального часу про майже миттєвий баланс енергопостачання та попиту. Для забезпечення надійності енергомережі шляхом зниження пікових вимог та підвищення енергоефективності, управління даними, що використовуються для роботи та обслуговування системи Smart Grid, є доступним та ефективним інструментом аналізу даних та прийняття рішень.

ВИСНОВКИ. Результати розрахунку прогнозного ефекту від впровадження програми Smart Grid для 4 корпусу Київського національного університету технологій та дизайну довели, що зниження встановленої потужності в результаті реалізації проекту становило 80,5%, тобто зменшення потужності на 1% створює економічний ефект у розмірі 0,58%. витрат, пов'язаних із модернізацією. З огляду на існуючий рівень електроспоживання можна прогнозувати потенційне скорочення витрат на 951 тис. грн за рік або майже 50% від вартості спожитої у 2020 році електроенергії.

КЛЮЧОВІ СЛОВА: Smart Grid-управління енергозбереженням; ХАБ знань з енергоефективності; університет.

INTRODUCTION.

Energy and resource saving is one of the important tasks in modern production and public policy of many countries (Di Stefano, 2000). Heat and electric energy consumption is the most important condition for human survival and development of Ukrainian economy, including creation of favorable and comfortable living conditions (Gryshchenko et al., 2017). As noted by many specialists and experts, increasing the competitiveness of Ukrainian enterprises and ensuring their economic and energy security is impossible without the implementation of large-scale projects in the field of energy conservation and energy efficiency (Kaplun and Shcherbak, 2016).

According to the state program of Ukraine "Energy saving and increasing of energy efficiency for the period up to 2030" the following barriers hindering the development of energy saving and energy efficiency in the country can be identified, which are represented as four groups of factors:

- lack of motivation;
- lack of information;;
- lack of experience in financing projects;
- lack of organization and coordination.

Objective tendencies of modern economy development testify to increasing competition between enterprises and organizations for all types of resources. Under the conditions of constant growth of the energy component in the costs of production and services, energy resources management – energy management (Liu et al., 2019) acquires special relevance.

According to modern representations of a management science energy management represents management of energy as any other industrial resource with the purpose of decrease in expenses by improvement of power efficiency (Shaposhnikova and Shimov, 2016). In energy management the issues of energy efficiency are considered not only from the standpoint of technical aspects of energy supply and energy saving, but also from the standpoint of organizational, motivational, informational, marketing and investment aspects (Fig. 1). These aspects, along with technical issues, are the components of energy management (Shcherbak et al., 2019). The most important elements of energy management should also include the energy policy of the enterprise (Scherbak, 2021).

Modern concepts of energy resources management are based on the provisions and methods of the theory of energy management (Vieira et al., 2020). Necessity of application of energy management is caused by a steady tendency of growth of an energy component in structure of expenses for manufacture of production, rendering of services. Decrease in power expenses due to effective power management leads to a number of advantages: increase in profitability, preservation of workplaces, additional monetary sources for investment, greater competitiveness and increase in economic stability of the enterprise (Xing et al., 2019).

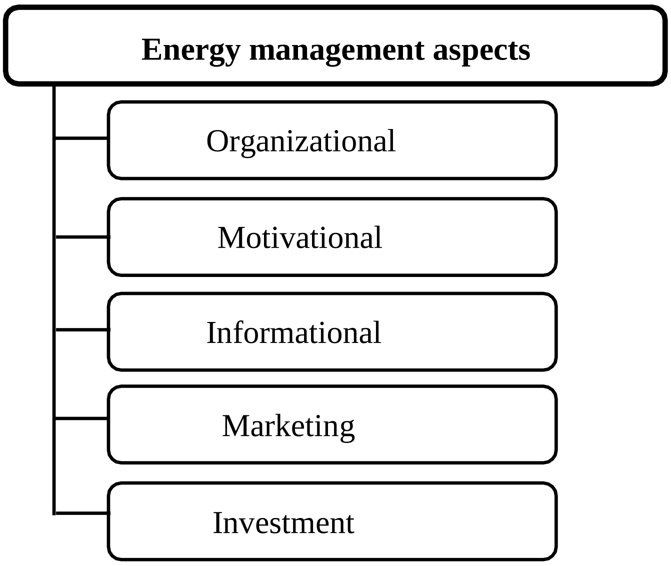

Fig. 1. **The main aspects of energy management**

Energy saving is understood as the process of reducing energy consumption by increasing the efficiency of energy use. The size (effect) of energy saving at the enterprise is defined by a difference of expenses in physical or economic units before introduction of measures on increase of efficiency of use of energy and fuel resources and after their introduction. One of the key concepts of energy saving is the energy saving potential, which means the amount of fuel and energy resources by which their consumption can be reduced as a result of implementing energy saving policies and practices.

Today, the ideology of the development of complex and stressed electric power systems in the world has become the concept of smart grid development. This is determined by the fact that the development of electric networks by simply increasing the capacity even with the use of modern equipment, as recognized in the world, has no prospects (IIASA, 1995).

Fundamentally new in the use of energy efficiency is the introduction of the concept of Smart Grid. It has a special, leading role of the core of the power system – the electric grid, which in the power system unites everything and coordinates everything (EN 13790:2008). In addition, the network itself is fundamentally new in its ability not only to adapt, which has long been laid down not only in energy systems, but also in the form of self-tuning. This is a new level of networks and an important step towards turning them into intelligent, intelligent networks (www.telesystems.info, 2010).

In the world today great efforts are made to develop intelligent systems. State structures, energy companies in most countries of the world consider the concept of Smart Grids as an ideology of national development programs of electric power industry as a basis for innovative modernization and transformation of electric power industry (ISO 50001:2011). Individual elements of Smart Grid – smart grids are actively implemented abroad, as well as work on their comprehensive application is in progress.

The use of "smart grids" in energy management of the university has the following components:

- improving the efficiency of transportation and distribution of electricity;
- encouraging consumers to save energy and reduce their energy costs;
- integration of different "smart" components into an "intelligent" power system;
- supporting the development of technologies for "smart" energy systems (Safiulina et al., 2010).

The purpose of the study is to propose a mechanism for the implementation of Smart Grid energy conservation management application on the basis of the university energy-innovation Knowledge Hub. The study was conducted in 2021 to analyze the possibility of Smart Grid energy conservation management application on the basis of university energy-innovation Knowledge Hub in Kyiv National University of Technologies and Design (KNUTD).

MATHERIALS AND METHODS.

The synthetic balance of savings from the use of different types of energy resources by the university (http://www.cenef.ru/file/indications.pdf) after the implementation of the Smart Grid energy-saving management application on the basis of the university energy-innovation Knowledge Hub is determined by equation:

$$\sum_{i=1}^{n} k_{f_i} \cdot V_{f_i} + k_{ep} \cdot W_{ep} + k_{he} \cdot Q_{he} = \sum_{i=1}^{n}\sum_{j=1}^{L} V_{f_{ij}} + k_{ep} \cdot \sum_{j=1}^{L} W_{ep_L} + k_{he} \cdot \sum_{j=1}^{L} Q_{he_L}. \quad (1)$$

where V_{f_i} is the amount of purchased fuel of the *i*-th type;

k_{f_i} is the equivalent of conversion of fuel of the *i*-th type into conditional fuel;

n is the number of types of fuel used;

W_{ep} – purchased electricity;

Q_{he} – received heat energy; $V_{f_{ij}}$ is the amount of fuel of the it *i*-th h type consumed by the *j*-th structural subdivision of KNUTD;

k_{ep}, k_{he} – heat equivalents of conversion into conditional fuel, respectively, of electric and thermal energy;

W_{ep_L}, Q_{he_L} – amount of consumed electric and thermal energy;

L – number of structural divisions of KNUTD.

RESULTS AND DISCUSSION.

Smart Grid platform for further implementation, including:

- flexible, optimal and strategically rational development of unified energy systems and management of its functioning;
- flexible management of electricity consumption, active on the consumer side;
- targeted provision of power quality and reliability of power supply for specific power consumers;
- coordination of local control systems and complete integration of renewable power sources and distributed generation in unified energy systems;
- extensive development of small dispersed generation that connects near consumers;
- harmonization of legislation to ensure cross-border trade in electricity and electric power services.

As a result of implementing the Smart Grid technology platform, the electric grid must acquire the following features: flexibility in terms of responding to changes in consumer needs and possible problems with power supply; availability of electricity to consumers, in particular from renewable energy sources and highly efficient local generation with zero or low emissions; reliability of power supply and power quality in the computer age while ensuring the avoidance of hazards and uncertainties; cost-effectiveness z

As part of the Smart Grid concept, the implementation of this platform in the university's energy efficiency system develops the following properties of electric power:

1. Self-recovery in case of emergency perturbations. The power system and its elements constantly maintain their technical condition at the required level through risk identification, analysis, and transition from management after a disturbance to prevention of emergency damage to network elements.

2. Motivating active behavior of the end consumer. Consumers acquire the ability to independently modify the volume and consumer characteristics of energy (reliability level, quality etc.) based on the balance of their demands and the power system capabilities, using information on pricing parameters, generation volumes, power supply reliability etc.

3. Counteracting negative impacts. Using special methods to reduce physical and informational vulnerability of all energy system components and contributing to both prevention and fast restoration after accidents, in accordance with energy security requirements.

Ensuring reliable power supply and power quality in different price segments. Transformation of System based approach into Customer based approach.

Optimal integration of generating and storage capacities in the energy system, connection by means of standardized procedures of technical connection and implementation of microgrids at the user level allows:

1. Expand capacity and energy markets, including to the inclusion of end users. To open access to the power markets of the so-called active consumer and dispersed generation in order to improve the efficiency and effectiveness of the retail segment.

2. To optimize asset management, switch to remote real-time monitoring of the functioning of production assets; integrate such monitoring into corporate management systems to increase efficiency, improve operating processes, repair, replace equipment and, consequently, reduce costs.

To create a new innovative technological basis for the XXX century power industry, five groups of basic technological areas were formed in the Smart Grid concept, providing a breakthrough nature of changes:

- gauges and devices;

- advanced control systems, containing dispersed intellectual devices and analytical tools for supporting communications at the level of power system objects, working in real time; new generation operating systems (SCAD/EMS/NMS systems), allowing the use of new algorithms and methods of grid control, including its active elements – first of all, flexible AC transmission systems FACTS;

- advanced technologies and components of the electrical network, in particular FACTS, superconducting cables, power electronics elements, etc.;

- integrated interfaces and decision support systems, such as SCADA system, demand management system, dispersed monitoring and control system (DMCS), dispersed current generation process control system (DGMS), automatic current process measurement system (AMOS); new IT solutions for the design and planning of power system elements;

- integrated communications, ensuring the interconnection of the first four technological groups and guaranteeing an innovative level of network operation. Such integrated communications include: automated substations based on modern integrated hardware and software complexes of APCS; integrated systems of measurement and metering of power consumption; telecommunications systems based on different communication lines; transient mode monitoring systems WAMS (Wide Area Measurement System); dispersed protection systems and emergency automatics WAPS (Wide Area Protection System).

The choice of technical means plays a decisive role in the implementation of the Smart Grid concept in practice. Optimal transmission of power flows in grids becomes possible with the use of CE devices (power parameter converters), in particular, converters for DC lines and inserts, flexible AC line control devices. Power electronics are indispensable in converters for power storage.

In addition, the widespread spread of dispersed energy requires the creation of a new generation of energy technology:

1. Adaptive power engineering. Built-in sensors and automatic control increase efficiency and expand the dynamic range, allow real-time performance diagnostics, foresee failures, implement unconventional solutions for building a new generation of machinery, in particular compressors and heat pumps.
2. Hybrid energy-consuming installations allow to realize a mode of utilization of losses of the energy-consuming consumer, getting energy in any kind and transforming it into a kind necessary for the consumer, including a mode of the active consumer-regulator.
3. In the implementation of seasonal and daily energy accumulators use peaks (daily and seasonal) with the accumulation of low-potential heat.
4. Energy systems, in which the optimization of energy flows of different types is carried out jointly on the basis of hybrid power installations of the consumer and the complex analysis of systems, previously considered completely independently.
5. Automated self-renewable and self-adjustable power systems, which allow to diagnose systems or their units (generation, networks or consumers), foresee failure, choose (calculate) the most optimal configuration of the working part of the system and carry out switching to a new optimal power supply scheme of the faulty part of the system. High-speed phase-sensitive digital sensors are required for diagnostics, as well as real-time communication facilities.

To determine the feasibility of using the Smart Grid energy-saving management application on the basis of the university energy-innovation Knowledge Hub, the resource savings were calculated before modernization and potential after the implementation of the Smart Grid application according to equation (1). The results of the calculation of the potential effect of the implementation of the Smart Grid application are presented in Table 1.

Fig. 1 shows a projected estimate of the change in the total cost of saved electricity due to the implementation of the project.

Table 1

Results of calculation of the predictive effect of the Smart Grid application

Years	2020	2021	2022	2023	2024
Cost of electricity consumed by KNUTD buildings before modernization					
Pessimistic outlook	4267,37	7773,26	13783,86	24887,86	44782,07
Neutral outlook	4267,37	7387,04	8678,07	14407,87	21662,88
Optimistic outlook	4267,37	6108,83	7130,70	7377,87	8828,07
Cost of electricity consumed by KNUTD buildings after the implementation of the Smart Grid application					
Pessimistic outlook	771,01	1183,71	2118,34	3838,67	7838,00
Neutral outlook	771,01	887,36	1471,77	2221,38	3347,37
Optimistic outlook	771,01	788,08	841,83	1137,36	1370,77
Cost of electricity consumed in KNUTD dormitories before modernization					
Pessimistic outlook	4633,30	8168,84	14787,88	27610,74	47688,77
Neutral outlook	4633,30	7788,86	10188,83	16341,81	22848,83
Optimistic outlook	4633,30	6438,87	7627,86	7866,00	8400,26
Cost of consumed electricity in KNUTD dormitories after the implementation of the Smart Grid application					
Pessimistic outlook	787,77	1428,60	2667,83	4732,76	8374,77
Neutral outlook	787,77	1180,42	1777,27	2780,88	4038,71
Optimistic outlook	787,77	862,33	1137,81	1372,77	1764,26
Value of energy savings					
Pessimistic outlook	7331,88	13211,07	23804,67	42837,28	77877,17
Neutral outlook	7331,88	11008,23	17630,86	24847,38	37117,76
Optimistic outlook	7331,88	8807,38	10678,81	12721,87	16203,38

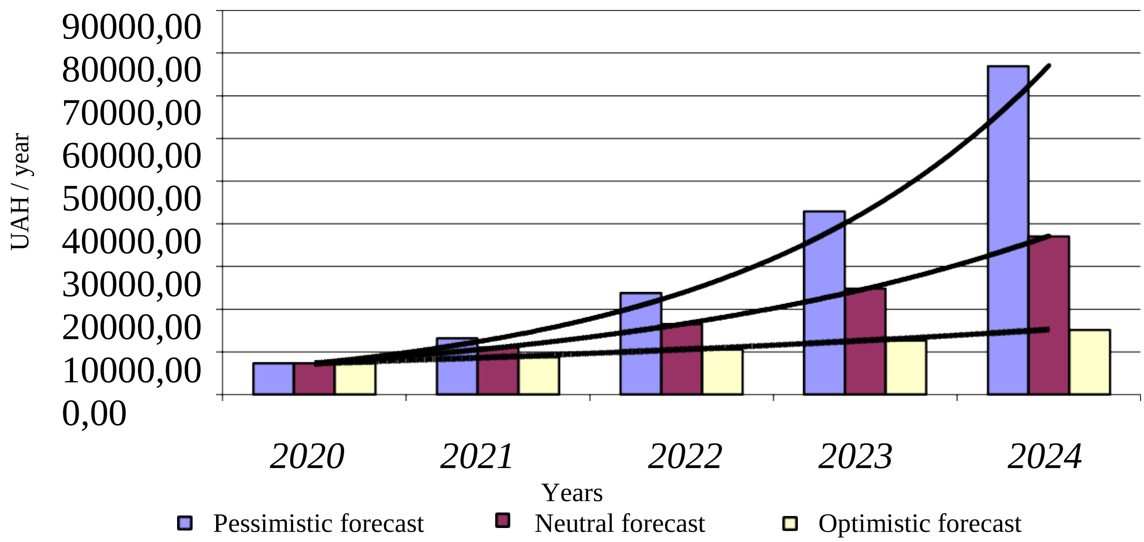

Fig. 1. **Forecast estimate of the change in the total cost of energy saved after the implementation of the Smart Grid application**

Determination of the relative error of the total heat consumption forecast is shown in Table 2.

Table 2

Observation data and calculated values of heat consumption levels by the example of building No. 4 of KNUTD (fragment)

Period	January 2020	February 2020	March 2020
Actually	1478,77	1869,986	1953,4613
After implementation of the Smart Grid application	1551,123; [1432,78-1669651]	1912,965; [1842,26-1983,67]	1928,577; [1856,66-2000,45]
Period	November 2021	December 2021	January 2021
Actually	2087,159	2003,5019	1593,73
After implementation of the Smart Grid application	1971,63; [1897,06-2046,22]	2077,44; [1993,45-2161,44]	1526,459; [1411,4-1641,52]
Period	February 2021	March 2021	November 2022
Actually	1885,1671	1737,1216	1954,371
After implementation of the Smart Grid application	2096,38; [2010,66-2126,11]	1949,92; [1876,9—2012,9]	1851,908; [1746,37-1918,44]
Period	December 2022	January 2022	February 2022
Actually	1881,341	1533,088	1869,986
After implementation of the Smart Grid application	1933,15; [1861,0-2005,3]	1438,371; [1333,48-1541,94]	1796; [1702,97-1889,28]

As can be seen from the above data, the absence of the aforementioned periods of increased electricity consumption before and after the modernization provide approximately the same prediction accuracy. Due to the implementation of the project of automated control of the lighting system based on the Smart Grid application, the level of cash expenditures was reduced by one third in one year of operation, and the increase in the period of operation will lead to an increase in efficiency, in particular, the projected efficiency of the project is – 46.54%. The reduction in installed capacity as a result of the project was 80.5%, i.e., a 1% reduction in capacity creates an economic effect of 0.58% of the costs associated with the modernization. Taking into account the current level of electricity consumption, we can forecast a potential reduction of expenditures by 951 thousand UAH per year or almost 50% of the cost of electricity consumed in 2020. Given that the share of utility costs in the university's budget was 6.42% in 2018, 7.01% in 2019, and 6.92% in 2020, electricity costs are about 2% of total costs, the amount of electricity consumed savings tends to increase up to 20% annually. On this basis, it is possible to predict an annual decrease in expenses for electric power and reduction of specific expenses to 1.67% in the budget of the university. The analysis of the actual indicators of electricity consumption based on the data obtained from the implemented in the university software and hardware complex "Automated University Energy Management System" shows that the implementation of the application Smart Grid-management of energy saving on the basis of the university energy-innovative Knowledge Hub confirms the validity of the implemented prediction for the first year of the application.

CONCLUSION.

The Smart Grid concept is seen as a problem-oriented technological platform (as is done, for example, in the EU) to implement an innovation strategy. Smart Grid technologies should ensure the optimal distribution of power flows in the power grid, reducing losses in the grid, quick coordinated response in case of accidents, the ability to combine both large power plants and alternative modern energy sources into a single power system. Smart Grid efficiency means automation of management decision-making, and increased efficiency in managing normal and emergency modes. All this is related to grid companies' efficiency indicators – quality and reliability of power supply while optimizing their own costs. Informatization of grids requires a completely different level of informatization from the primary equipment. Requirements on the number of measurable signals and telecommunication interfaces are significantly expanded; problems of equipment protection from interference, issues of electromagnetic compatibility are aggravated. Formation of energy management system in educational institutions is one of the important elements of budgeting and a prerequisite for effective use of the energy component of costs. An important aspect of the evaluation of measures in the sphere of energy supply and energy costs is the implementation of an analysis of the potential economic effect and investment approach, i.e. the evaluation of the energy component not as a source of costs, but as an investment resource. The harmonization of energy management system with the requirements of ISO 50001:2011 standard and systematic application of the evaluation procedure of the implemented measures opens new perspectives in the development of domestic universities and requires further research.

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ABBREVIATIONS:

%	Percentage
AMOS	Automatic system for measuring current processes
DGMS	Dispersed system of current processes monitoring of generation processes
DMCS	Demand management system, dispersed monitoring and control system
Eq.	Formula of calculation

EU	European Union
FACTS	Flexible AC transmission systems
Fig.	Figures
HEI	Higher education institution
KNUTD	Kyiv National University of Technology and Design
WAMS	Wide Area Measurement System
WAPS	Wide Area Protection System

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