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THE SYSTEMS OF BACKUP POWER SUPPLY BASED ON RENEWABLE ENERGY SOURCES FOR MOBILE FACILITIES

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СИСТЕМИ РЕЗЕРВНОГО ЕЛЕКТРОПОСТАЧАННЯ МОБІЛЬНИХ ПРИСТРОЇВ НА ОСНОВІ АЛЬТЕРНАТИВНИХ ДЖЕРЕЛ ЕНЕРГІЇ

Purpose. To substantiate the need for implementation of backup power supply systems based on renewable energy sources and intended for low-power consumers. To assess the renewable energy potential in Ukraine.

Methodology. Method of analytical processing of surveys on efficiency of renewable sources for autonomous backup power systems aimed at supplying low-power distant consumers and method of modelling alternative schemes of uninterruptible power supply have been used.

Findings. The necessity to make use of renewable sources in autonomous systems of backup power supply has been substantiated. Advantages of solar energy and wind energy in Ukraine for low-power consumers are emphasized.

Originality. The possibility of supplying electricity to low-power consumers through autonomous mobile systems has been considered. Alternative hybrid autonomous system of guaranteed power supply from renewable energy sources is proposed.

Practical value. Autonomous backup power systems will make it possible to reduce human impact on the environment and help use the potential of local renewable energy sources in Ukraine.

Keywords: *backup power supply, renewable energy, fossil fuels*

Problem statement. Energy is crucial for economic development and industry. Recently, with the rapid development of production and increased production capacity in Ukraine, there is a need to make use of all energy resources available. However, fossil fuels are exhaustible, their total amount decreases every year, and the environmental impact is global.

Introduction. According to the Ministry of energy of Ukraine, the demand for electricity in 2030 will amount to between 244 (pessimistic scenario) up to 315 (optimistic scenario) TWh. In the baseline scenario, the electricity demand will reach 282 TWh, which is 50 % higher than in 2010 (191 TWh). Primarily this will be due to increased consumption in industry (40 %) and in services (100 %) [1].

The overall intensity of GDP is several times higher in Ukraine than in developed countries of Western and Eastern Europe. For instance, in 2010, the energy intensity of GDP in Ukraine amounted to 0.55 ton of equivalent fuel per 1,000 dollars of GDP compared with 0.1 for Germany, and only 0.2 for Poland and 0.46 for Russia. High energy intensity in Ukraine is influenced by specifics of the structure of the national economy, the development of which is directed toward more energy-intensive industries. As a result, most sectors of the economy lag far behind the level of developed countries [1].

Currently the major part of generating assets and installations of electricity in Ukraine are outdated and ineffective. 42.2 % of overhead power transmission lines (PTL) with a voltage of 220–230 kV have operated for over 40 years, 64,4 % of the main equipment of transformer substations significantly exceeded the estimated technical resource [1].

One of the priority directions of development of backbone networks is a program for the modernization of high-voltage lines and substations, aimed in particular at reducing energy losses. Another option is the introduction of the so-called networks with distributed generation based on renewable energy sources (RES).

When developing measures for the reduction of energy consumption in Ukraine, it is also necessary to take into account structural and technical aspects of energy saving potential. The structural component reflects the decrease in the share of energy-intensive industries in GDP due to the development of industries with low energy and materiality as well as knowledge-intensive industries. The technical component, in turn, describes the decrease of energy production, conversion, transportation and consumption of energy by introducing the latest energy efficient technologies and energy saving measures.

According to research [2], losses of electricity transmission in the networks of the country are influenced, inter alia, by the current state of distribution networks. The use of obsolete equipment leads to increased losses due to the dynamics of operating parameters in the elements of power supply systems (PSS) for the period of operation and, consequently, to the increase of active resistance of overhead transmission lines and losses of idling of power transformers.

To ensure the effective development of energy in Ukraine, from 24.07.13 for the period up to 2030, the energy strategy was adopted [1], in which among other purposes, the increase in energy consumption efficiency and its usage as well as reduction of anthropogenic impact on the environment, is emphasized. Based on these objectives and given the economics of mining the deposits of fossil fuels, the main tasks and directions of implementation of the strategy are supposed to intensify production of domestic energy resources and to increase amounts of energy generated by RES.

The development of green energy is a promising direction owing to which people expect the increase in the level of energy safety and reduction of anthropogenic impact on the environment. According to the strategy, as is supposed, the share of renewable energy in the overall balance of installed capacity will increase by 2030. The ratio of the share of generation from power plants that use wind, solar, biomass and small rivers will be determined taking into account the trends in the reduction of specific capital costs for the construction of these power plants.

In the long term, to implement RES in Ukraine, one should consider whether they are economically competitive or not alongside with conventional sources, and take into account the potential benefits from the development of RES. Today the cost of generation of electricity based on RES is much higher than the cost of conventional power generation [1, 3]. Therefore, the exploration and development of RES requires the use of mechanisms of supporting and stimulating, for example, the introduction of a green tariff.

At the same time, it will help cut the costs for the construction of facilities for generation of energy from renewable sources, and to increase the ratio of the installed capacity utilization (capacity factor). As is known, according to the International Agency on renewable sources, the cost of electricity production from RES have equaled or fell below the cost of fossil fuels for the majority of technologies in many parts of the world [1, 4].

Thus, due to the rapid development of the technology and the competitive preference of renewable energy if compared with fossil fuels, as well as owing to the return costs of capital investment and of depreciation, the cost of electricity generation from RES may equal or even be lower than the cost of conventional power generation in the regions of Ukraine.

At the beginning of 2016, according to the National Commission that carries out state regulation in the energy and public utilities (NCREPU) sectors, the share of installed capacity of electricity producers from solar and wind are respectively 431.7 and 426.1 MW. In 2015, a tendency to increase capacity of electricity producers from RES is clearly discernible in Ukraine. At the end of 2015, "Green" tariff is set for 127 economic entities, which produce electric energy by means of 227 electric power facilities using alternative energy sources, including 15 new entities in 2015 [5].

It should also be noted that at this point the Chernobyl zone is an area of untapped potential and remains promising for renewable energy, particularly the solar one. In the near future, solar power plants of high capacity are to be built on the territory of Chernobyl [6].

On the basis of the current state of electrical networks, of available regulatory capacity, of normalized cost of electricity production from RES and decreased expenditures for the construction of facilities for power generation from RES, the forecast is made on the appropriate total capacity of renewable energy until 2030 at 12.6 % of the total installed capacity, or 8 GW (14 GW including large hydro power stations), of which 4 GW – solar power and 3–4 GW – wind energy. The volume of electricity generated from renewables is 14 TWh (28 TWh including large hydro power stations). However, these indicators may increase due to the changes in factors mentioned above [1].

Unsolved aspects of the problem. A special case of the power systems is standby power systems, which are used to supply mobile low-power facilities/devices in places where mains supply is not possible, and the construction of small stations or installation of transmission lines is not an economically feasible solution, for example, military radar stations or apparatus of electrical prospecting [6]. The majority of such systems use low power (10 kW) diesel or gasoline generators as primary power source. The use of generators in the backup power supply is not the best solution because of their short term of service, emissions of oxides of harmful substances (CO, CO_2, NO_2), related fuel costs, the need for add-on devices during the realization of technical arrangements or routine maintenance etc.

Analysis of the recent research. In publications of foreign scientists and researchers, one can see a marked tendency in the analysis of the usage of renewables as power sources for mobile (portable) consumers, which are far remote from the electrical network.

As the most promising source of green energy, a special attention is focused on solar energy. Therefore,

Kannan Nadarajah [7] notes that solar energy is the best option because of its prevalence, considerable solar radiation and total surplus of it in nature. The sun is an inexhaustible source of energy. The usage of solar energy can provide a growing efficiency in comparison with the other renewables [7].

In addition, the problems of environmental pollution and their consequences are emphasized. The designs for autonomous power supply systems based on solar cells and the usage of add-on devices, hubs, through which it is possible to increase the proportion of solar radiation converted to electricity are offered.

Recently issued foreign publications on the studied subject are the ones written by the authors from many European and other countries, including Philip Sandwell and J. G. Castellanos from the UK, Vicente Salas from Spain, Joydip Jana from India, Marco Bortolini and Alireza Haghighat Mamaghani from Italy, Manuela Sechilariu and David Tsuanyo from France, Shafiqur Rehman from Saudi Arabia, Nasrudin Abd Rahim from Malaysia, etc. In the publications of these authors, the issue of effective implementation of renewable sources to the power backup systems used to supply energy to the remote from the general electrical grid customers is solved in a varying degree.

The question of autonomous systems of backup power supply is also widely studied in the countries of the former Soviet Union. Thus, Fedorov A. Yu., Grigorash O. V., Vinnikov A. V., Kozukov D. A., Abasova T. S., Andrianova, L. P., Chetoshnikova L. M., Uskov A. E., Yudaev I. V. and other authors are considering the possibility of developing and using systems based on RES with the aim of reducing harmful emissions.

The objective of the article. The aim of this work is to evaluate the possibilities of using renewable sources on the territory of Ukraine and to put into operation autonomous systems of backup power supply based on renewables with the purpose of supplying energy to the low power and remote consumers.

Presentation of the main research. For comparison of different types of RES, concepts of the total, technical and economic potentials are widely used in the literature. The total or theoretical potential of renewable energy sources is the annual amount of energy, which is contained in the type of RES at its full transformation into useful consumed energy. The technical resource of RES is the part of total potential, the conversion of which into useful energy is possible under the current level of technical facilities development and in compliance with existing requirements for the protection of the natural environment. The economic renewable energy potential is the part of technical potential, the conversion of which into useful consumed energy is economically feasible at a given level of prices on fossil fuels, heat and electricity, equipment, materials, transportation, wages, etc. [8].

According to "ESCO" [9], the values of the described RES potentials are quite high in Ukraine. Table 1 shows that solar energy and wind power are the most promising renewable sources.

When designing power backup systems, the sources, which are the most appropriate to use, split into solar energy or wind energy. A significant gross potential of solar radiation, air masses and their relative inexhaustibility contribute to this choice. On the contrary, according to [10], the use of wind energy requires considerably greater economic resources.

When analyzing the usage of wind energy, it was determined that wind turbines have been used for a long time to generate additional electricity in developed countries. Almost all the windmills have low maintenance costs, whereas investment costs (US $ 4500–5500 kW^{-1}) and maintenance costs (27 US $ $kW.h^{-1}$) are rather high [10]. Coefficient of performance (COP) of the received energy essentially depends on the geographical location of the wind turbine (WT). WT itself is characterized by a low conversion efficiency of electricity and a small coefficient of installed capacity utilization.

Compared to WT, the solar cells are characterized by a low investment (1200–1950 US $ kW^{-1}), operating costs and maintenance costs (0.2 US $ $kW.h^{-1}$) [10]. As in the case of WT, the efficiency of solar cells depends on the geographical location and time of year. Solar cells have low conversion efficiency and small coefficient of installed capacity utilization, but given the rapid development of solar energy [7], the efficiency of solar cells in the near future will only increase, while the effectiveness of WT, for technical reasons, cannot reach 100 % [11]. At best happened, only slightly more than half of the energy of the incoming wind flow can be used to convert

Table 1

The potential of renewable energy sources on the territory of Ukraine

Renewable energy source		Total potential	Technical potential	Economic potential
Solar energy, MWh/year		$681.9 * 10^9$	$327.6 * 10^7$	$51.1 * 10^5$
Wind energy at variable annual speed at a height of 15 m, kWh/m^2 year	<4.5	1120	200	55
	4.5	2010	390	74
	5	2810	520	96
	5.5	3200	620	108
Hydropower of small rivers, mln. kWh/year		12 290	8113	3684
Low-grade thermal energy wastewater, MWh/year		66 469	32 666	12 249

the kinetic energy into energy of rotation of the propeller. This is because the air flow must have some kinetic energy to get to the area beyond the propeller. However, WT, unlike the solar cells, can generate electricity even at night.

For the most effective usage of solar energy, one must take into account its seasonality and intensity. Thus, accounting for average levels of solar radiation for the regions of Ukraine, we can conclude that solar panels are worth using in summer to get more efficiency. In winter, the usable capacity will be much lower [11].

Fig. 1 [10] shows that solar activity dominates in the south of the country and in the central parts mainly from April to October – 7 months, and 5 months in the north – from May to September. However, PV equipment can be effectively used throughout the year, as the average annual amount of total solar radiation arriving at a 1 m^2 surface ranges from 1070 kWh in the Northern regions up to 1400 kWh in the South if the sky is cloudless [10].

Therefore, in Ukraine there are all favorable external factors for the implementation of backup power supply systems based on the RES, in particular solar energy.

It should also be noted that the advantage of solar power usage as an additional source for the Ukrainian enterprises, which pay for the used electricity by two-tariffed system, is the decrease of economic costs in the hours of morning high loads.

Whenever solar PV modules are installed, one should take into account their inclination to the horizon, as it affects the amount of convertible solar radiation, and moreover, the required area appropriate for the installation. If it is a mobile solar installation, it is necessary to create conditions for safe configuration of modules in order to avoid their damage during transportation and also to consider the possibility of increasing capacity by installing additional modules.

Photovoltaic modules are usually installed on special structures, which ensure their optimum orientation to the sun and secure attachment to various types of installation surface.

For maximum efficiency, PV modules should be assembled so that sunlight falling on the module surface at the angle of 90° I is provided. This is only possible when a special rotating structures with dose tracking system – sun tracking system is used. Such solar installations, except for the obvious advantages of maximum utilization of solar energy, are quite expensive facilities and consume insignificant but constant amounts of energy and require more space for installation if compared with fixed systems. Therefore, usually compromise is to be made whenever the efficiency of the system and its assembly cost are regarded. In most cases, in the photovoltaic systems, stationary design is preferable.

The scope of autonomous systems application can be different from the low-power field and farm units to more powerful military facilities, etc. Table 2 shows low power electrical consumers.

For example, military radar station (RLS) P-18 is powered by diesel unit AD-10 (4Ч8.5/11) [12]. It is known that the service life of AD-10 is 12 thousand hours, i.e. 1,4 years of continuous operation. The usage of solar panels in this case will significantly reduce the maintenance cost because solar panels do not require

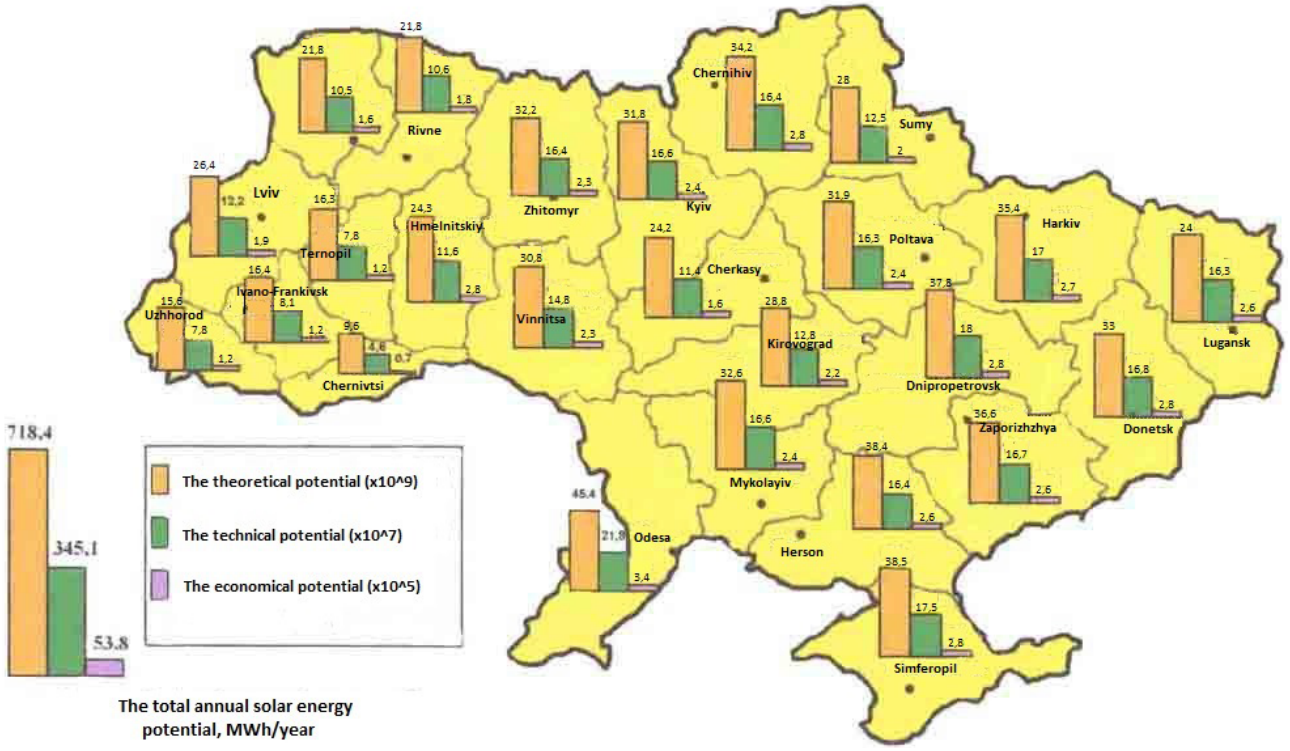

Fig. 1. The potential of solar energy in Ukraine

Table 2

Low power electricity consumers

Mobile	Used energy source	Remote	Used energy source
Low power generators for geological prospecting	Diesel or gasoline generator sets up to 10 kW	Appliances for village farms	Internal combustion engines or diesel generator sets 1.5–50 kW
Military radar stations	Diesel or gasoline generator sets up to 20 kW	Low power household appliances	Diesel or gasoline generator sets up to 10 kW

renovation and can serve from 10 to 15 years. In addition, solar panels do not require fuel for their operation. Another example of the autonomous power systems usage is geophysical equipment for electroprospecting. The main consumer of electricity in such facilities is the direct current source. To power this equipment, the low power gasoline generators (up to 5 kW) are widely used nowadays. Since the term work of electroprospecting expedition lasts up to 2 months, the usage of autonomous standby power systems based on renewable energy sources, in this case, will reduce the amount of used fuels.

Standby power systems are widely used in transport, aerospace and military technology, on stationary objects and recently, in agricultural production. Standby power systems provide electricity mainly for responsible consumers (consumers of the 1st and 2nd category of reliability) which are computer control systems, communication and information processing, automatic control systems of technological processes and entire industrial complexes.

In addition, an important function is assigned to transport systems that provide electricity to consumers in remote areas, including the cases of emergency situations.

As far as the use of wind energy is concerned, implementation of the combined mobile system of uninterruptable power supply will be the most appropriate. This system represents a parallel and/or sequential work of wind turbines and diesel (petrol) engines unit per one generator. The design of the system makes it possible to provide a continuous supply of mobile facilities through the use of each motor. Under optimal environmental factors, power supply to consumers is provided at the expense of a wind turbine. In turn, at lower wind speeds almost equal to boundary values, at which generated power will not reach the required level, the system switches to the operation of the internal combustion engine. Thus, the power supply of mobile consumers will be continuous and will not depend on external factors. Simplified electrical circuit of combined system is shown in Fig. 2.

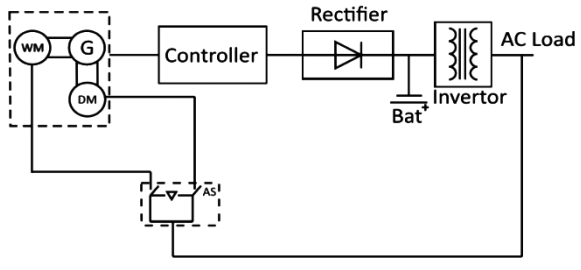

Fig. 2. The electric scheme of combined mobile system of uninterruptable power supply

Conclusions and recommendations for further research. In the result of the analysis, the feasibility of usage of the backup power supply autonomous systems based on renewable energy sources for the low-powered consumers is justified. Given the gross technical and economic potential of renewable energy sources on the territory of Ukraine, it is established that the most promising renewable resource for the usage in backup power systems is the solar energy.

The usage of autonomous backup power supply systems on the territory of Ukraine will reduce the anthropogenic impact on the environment and make possible to employ the potential of local resources of renewable energy.

Nowadays the only significant negative factor for the creation of systems based on RES is the price for electrical equipment. But in the coming years, the use of conventional fuels will require the introduction of more stringent regulatory requirements to reduce CO_2 emissions, primarily to minimize the use of fossil fuels by increasing the prices or taxes on their use and in turn by providing benefits for implementation of energy systems with renewable energy sources

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Мета. Обґрунтування необхідності впровадження систем резервного живлення малопотужних споживачів на основі відновлюваних джерел енергії. Оцінка запасів відновлюваних джерел на території України.

Методика. Використані методи аналітичної обробки оглядових матеріалів з енергозабезпечення малопотужних віддалених енергоустановок і моделювання різних схем безперебійного живлення.

Результати. Обґрунтована доцільність використання відновлюваних джерел в автономних системах резервного живлення.

Наукова новизна. Розглянута можливість живлення малопотужних споживачів електроенергії за рахунок мобільних систем автономного електропостачання. Запропоновано варіант комбінованої автономної системи гарантованого електрозабезпечення з використанням відновлюваних джерел енергії та обґрунтована оптимальна схема.

Практична значимість. Впровадження автономних систем резервного живлення на території України дозволить знизити антропогенний вплив і реалізувати потенціал місцевих ресурсів відновлюваних джерел енергії.

Ключові слова: *резервне електроживлення, відновлювані джерела енергії, викопні види палива*

Цель. Обоснование необходимости внедрения систем резервного питания маломощных потребителей на основе возобновляемых источников энергии. Оценка запасов возобновляемых источников на территории Украины.

Методика. Использованы методы аналитической обработки обзорных материалов по энергообеспечению маломощных отдаленных энергоустановок и моделирования различных схем бесперебойного питания.

Результаты. Обоснована целесообразность использования возобновляемых источников в автономных системах резервного питания.

Научная новизна. Рассмотрены возможности питания маломощных потребителей электроэнергии за счет мобильных систем автономного электроснабжения. Предложен вариант комбинированной автономной системы гарантированного электроснабжения с использованием возобновляемых источников энергии и обоснована оптимальная схема.

Практическая значимость. Внедрение автономных систем резервного питания на территории Украины позволит снизить антропогенное воздействие и реализовать потенциал местных ресурсов возобновляемых источников энергии.

Ключевые слова: *резервное электропитание, возобновляемые источники энергии, ископаемые виды топлива*

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