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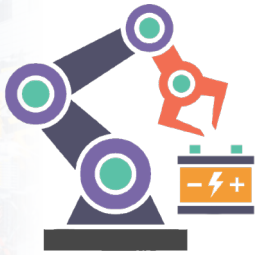

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Structure Optimization of Decentralized Photo-diesel Power Supply Systems for Remote Consumers on the Example of Ushbiik Village

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Abstract. *The purpose of this article is to study the possibility of introducing and optimizing the structure of decentralized photo-diesel power supply systems for remote consumers in Kazakhstan using the example of the selected area. The problems of power supply to remote territories and consumers with one-way supply have been studied, as well as the main reasons for shutting down the power system. In this regard, the power supply of remote consumers is an urgent task for the development of the energy industry in our country. The analysis of earlier studies and trends in improving this topic has been carried out. We have calculated the power consumption of electrical energy in the selected area during the peak period and, based on the data obtained, analyzed the application effectiveness and the main advantages of photo-diesel power supply systems. Based on the experience of foreign manufacturers, the main components for the photo-diesel power supply system have been selected.*

Keywords: *hybrid power supply systems, photo-diesel power supply system, diesel power plant, electrical energy consumer, power supply, power system.*

Introduction. Optimizing the structure of decentralized photo-diesel power supply systems for remote consumers in our country is a hot topic today. The vast territory of Kazakhstan and the inaccessibility of the local landscape complicate the energy supply for remote consumers from centralized

energy systems. In recent years, emergencies in the power system due to the deterioration of atmospheric air and abnormal weather phenomena have become more and more pronounced. The reasons for this are various factors associated with the lifetime of electrical equipment and external weather phenomena. One of these cases was identified at 220 kV substations in Atyrau electrical networks in January 2021 [1, 2]. It was found that the main cause of spark discharges and arc flashes in outer insulation of electrical equipment was the abnormally rapid contamination of the insulation of high-voltage equipment at the substation with conductive precipitation in the form of salt fog and drizzling rains. Mass outages led to significant interruptions in the power supply of enterprises and organizations of the Atyrau region, shortage and deviation of electric voltage for the oil–production enterprises and for the population of the region in the winter period.

Taking into consideration the intermittent operation of the power system and the lack of electrical energy at different times of the year, there has been an increasing interest in hybrid power supply systems (HPSS) with renewable energy sources in recent times in our country. This makes it possible to supply electrical energy uninterruptedly to remote consumers by means of decentralized photo-diesel power supply systems.

The algorithms for the operation of the resource mathematical model of solar energy were considered in article [3]. The mathematical model is based on the use of databases containing actual observational data on meteorological parameters. The current state and prospects for the development of fuel and energy complex were studied in similar article [4]. There are not many organizations in the world providing truthful information about statistical and predictive studies of world energy. According to the forecasts presented by the International Energy Agency (IEA), the world energy consumption can increase to about 1.5 times by 2035. Fossil fuels will continue to dominate the global energy mix, from 35% in 2007 to 30% in 2035 due to the expected rise in oil prices.

Some hybrid electric energy storage devices were studied in [5-7]. The main energy storage systems are hybrid systems based on long-term storage systems – batteries, and short-term storage systems – supercapacitor batteries, which make it possible to increase controllability, reliability and efficiency of operation, including decentralized and non-traditional sources of electricity in the system. Nowadays, lead-acid, sodium-sulphur, lithium-ion and nickel-cadmium batteries are widely used in autonomous power supply systems in the form of energy storage devices.

Hybrid energy storage devices (HES) can be used during peak loads and swamping load curves with the installed capacity of 1.5 MW, 5 MW, 20 MW, 50 MW and 3-5 hours per day operation. That allows you to get the following advantages of reducing the load on power equipment by accumulating energy instead of the cost upgrading the network infrastructure and reducing operation and maintenance costs [12].

We have chosen the village of Ushbiik, located in Zharmin district of the East Kazakhstan region as an example of a remote consumer. Power outages are common in this region. The main source of electricity comes through the overhead power lines OPL-110 kV Zhangiztobe-Shulbinskaya HPP, which comes from the overhead line LLP «NPP Shulbinskaya HPP». The substation has an external oil transformer EOT – 2500/110/6 kV. There are seven complex transformer substations of 6 kV in the village. They supply electricity for about 400 consumers, among which there are 50 consumers related to legal entities. Outages of overhead lines in winter are very high. The reasons for shutdowns are external factors in the form of heavy snowfall and obsolescence of power electrical equipment. On average, shutdowns in winter are 3-4 times per month. In summer, scheduled repairs are carried out for the reliable operation of electrical equipment, which leads to frequent outages.

Research methods. The research method is economic and mathematical modeling, as well as analytical research and comparative analysis of existing autonomous power supply systems. When analyzing we studied the reasons of outages and their effects on local residents and the enterprise. We analyzed the weather situation in the selected area and the amount of electricity consumed. We built an economic and mathematical model; we defined the economic feasibility of installing HPSS equipment.

The population of Ushbiik village is about 1500 inhabitants. There is an asphalt-concrete plant near the village. This, in its turn, leads to an even greater increase in electricity consumption. The reasons for disconnection from the main supply lines are breakage of overhead lines, severe overheating of the power transformer at peak load indicators, moral obsolescence of the power electrical equipment. During the autumn-winter period, the service is complicated by strong weather phenomena and the remote location of the studied village. In this regard, we propose a photo-diesel power supply system for remote consumers and the optimization of its structure. As a variant of the energy complex, we choose a system with two energy sources, each of which being able to cover the needs of the electrical load at certain time intervals, and characterizing by maximum of opportunities to replace diesel generation with renewable energy. This solution allows you to save more diesel fuel, reducing harmful emissions into the atmosphere.

Research results. The diesel power plant (DPP) is a power-generating unit consisting of an interconnected diesel engine and an alternator. The equipment is mounted on a solid metal frame. The fuel tank is designed for 6-8 hours of diesel power plant operation. The power plant is provided with a local monitoring and control system – a control panel. The operating principle is based on the combustion of fuel in the cylinders of a diesel engine.

The fuel is transmitted through a crank mechanism to the engine crankshaft. The crankshaft of the engine is connected to the rotor shaft of the alternator by means of a flexible coupling. The rotating rotor induces an alternating voltage in the stator windings. This voltage is applied to the connected consumers. The diesel power plant has a different range of rated capacities – from 10 to 3300 kVA in a single unit. The DPP power can be increased due to the combined operation of the units in a parallel group [8, 9].

Solar photovoltaic plants generate electricity by directly converting solar radiation energy into electricity.

The possibility of DPP turning off during periods of high indicators of the potential of a renewable energy resource is achieved by complicating the composition of the hybrid energy complex and the algorithms for controlling its elements.

The connection diagram of the hybrid power supply system of the type in question is shown in Figure 1. The presented scheme of the hybrid energy complex provides for the unification of various

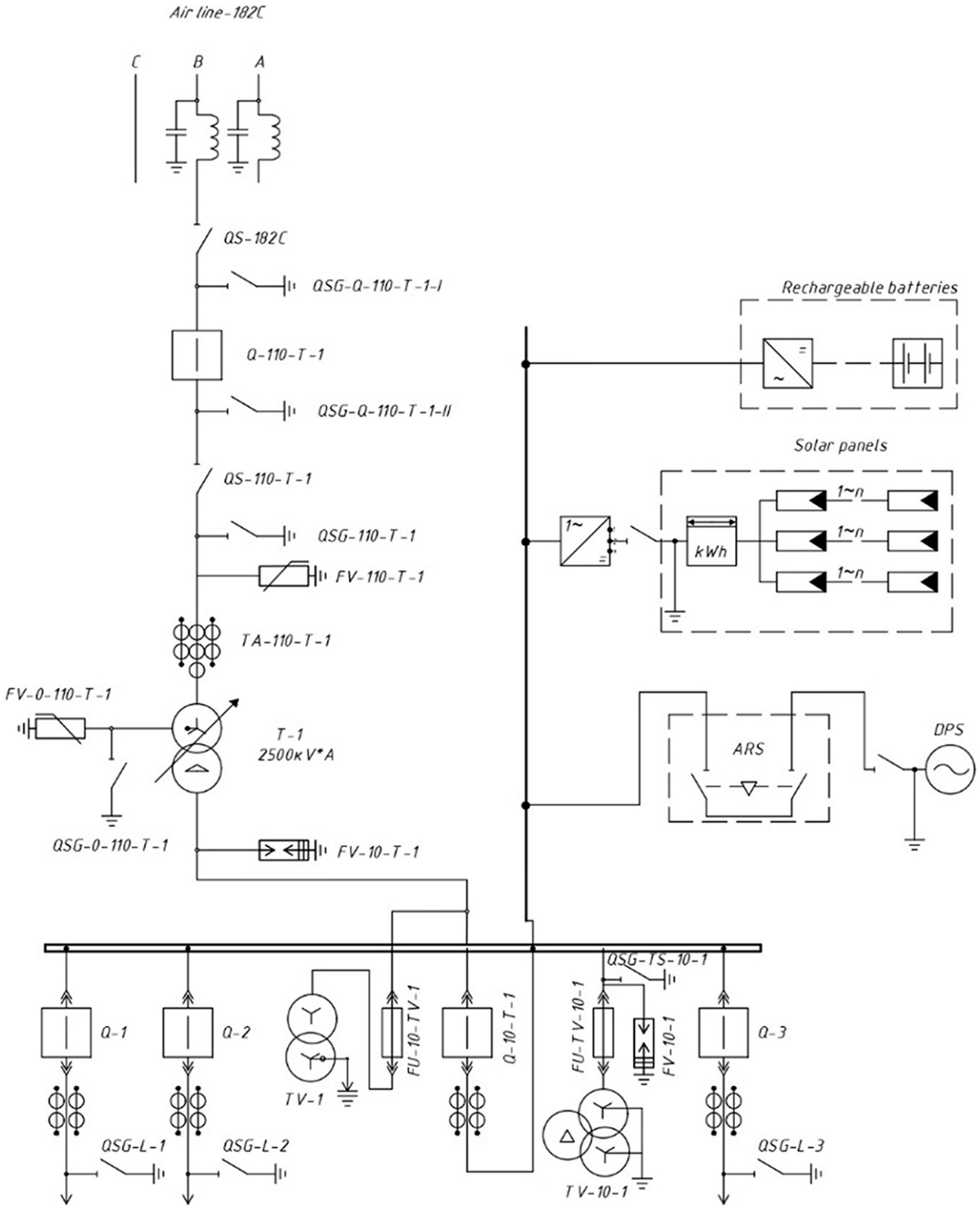

Figure 1 – Hybrid energy complex with DES at the existing PS110/10 «Ush-Biik» substation

sources of electricity on a 10 kV AC bus at an existing substation.

As an optimization of the structure of the photo-diesel power supply system, it is proposed to use solar panels manufactured by NwComp Solar (JUP6). Table 1 below shows the characteristics of the solar module.

The above modules are already used on an industrial scale and have proven themselves well in terms of quality.

The hybrid inverter HPS150 will be used as «all-in-one». The ATESS HPS bi-directional battery inverter is designed for an energy storage system, it converts the direct current generated by the battery into alternating current and supplies it to the load/network, and can also receive energy from a solar inverter or from the network to charge the battery to ensure uninterrupted power supply to the consumer. Figure 2 shows the schematic diagram of the inverter.

High-capacity LFP lithium-ion battery with aluminum housing with a service life of 6000 cycles. Figure 3 below shows the lithium-ion battery module BR138.

Table 3 shows the technical characteristics of the lithium-ion battery module BR138 and lead-acid sealed Hoppecke net.power 12V 170 batteries.

The advantages of a lithium-ion battery over lead-acid sealed Hoppecke net.power 12V 170 batteries are cheapness and long service life.

Compared to traditional batteries, lithium-ion batteries charge faster, their capacity is larger, they are more powerful, weigh less and last longer than currently used lead-acid batteries.

During the period of high potentials of the renewable energy resource, the DPP is switched off. Fluctuations in the consumed and generated power from RES are damped by the energy reserve in UPSS batteries, which makes it possible to reduce the number of DPP starts [10].

The average daily incident short-wave solar energy experiences extreme seasonal fluctuations throughout the year [11]. The brighter period of the year lasts 3.8 months, from 28 April to 23 August, with an average daily incident shortwave energy per

Table 1 – Technical Characteristics of NwComp Solar Solar Panels

Name of the manufacturer's company	JUP6
Country of origin	China
Module type	polycrystal
Module efficiency, %	15,9
Unit power of the module, W	260
No-load voltage, V	37,98
Voltage at the point of maximum power, V	30,63
Current at the point of maximum power, A	8,49
Short-circuit current, And	9,04
ambient operating temperature, °C	–40,0°C ... +85°C
Overall size, mm	1650x991x40

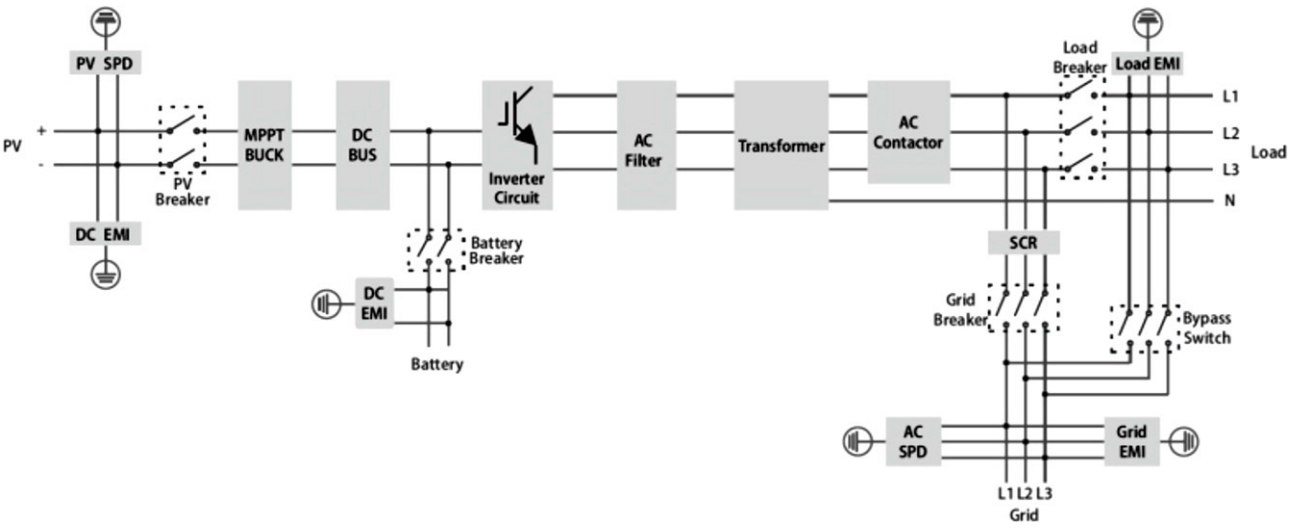

Figure 2 – Schematic diagram of the inverter

Table 2 – Technical characteristics of the Atess HPS150 hybrid inverter		
Name	**Unit of measurement**	**Quantity**
AC (connected to the network)	Atess HPS150	
Full power	kVA	165
Rated power	kW	150
Rated voltage	V	400
Rated current	A	217
Voltage range	V	360-440
By frequency rating	Hz	50/60
Frequency range	Hz	45~55/55~65
THDI (Distortion Factor sinusoidality current curve)	%	< 3%
PF		0.8 lags~0.8 is ahead
AC connection		3/N/PE
AC input	kVA	240

Figure 3 – Lithium-ion battery module BR138

Table 3 – Technical characteristics of the BR138 lithium-ion battery module and lead-acid sealed Hoppecke net. power 12V 170 batteries		
Name	**BR138**	**Hoppecke net.power 12V 170**
Configuration / Type of execution	12S2P	maintenance-free lead-acid AGM VRLA
Rated power	200 Ah	170 Ah
Rated energy	7.68 kWh	-
Rated voltage	38.4 V	12 V
Voltage range	33.6-43.8 V	-
Rated charge/discharge	0.5 S	-
Maximum charge/discharge	1 C	-
Internal resistance to alternating current	≤ 10 mOm	-
Size (W/H/D), mm	360/300/515	541/125/302
Weight	≤ 65 kg	64,5 kg

square meter above 6.3 kWh. The brightest month is June with an average of 7.5 kWh.

The darker period of the year lasts 3.5 months, from October 28 to February 12, with an average daily incident shortwave energy per square meter below 2.5 kWh. The darkest month is December, with an average of 1.3 kWh.

The category of cloudiness was studied in the village of Ushbiik. According to the data obtained, it turned out that in winter it is very cloudy. The rest of the year is characterized by clearer days. Figure 4 below shows a graph of the area's cloudiness.

Shortwave radiation includes visible light and ultraviolet radiation. The average daily incident shortwave solar energy experiences extreme seasonal fluctuations during the year. Figure 5 is a graph of the average daily incident shortwave solar energy.

Conclusion. The following conclusions can be made based on the analysis of references data, previously conducted scientific studies and the obtained results:

The disconnection from the main power system makes all consumers highly dependent on it, which leads to frequent outages. The main reason for all outages is the obsolescence of power electrical equipment and external factors in the form of abnormal atmospheric phenomena.

We have applied some research methods, such as economic and mathematical modeling, analytical research and a comparative analysis of existing autonomous power supply systems.

We have studied the current state and prospects

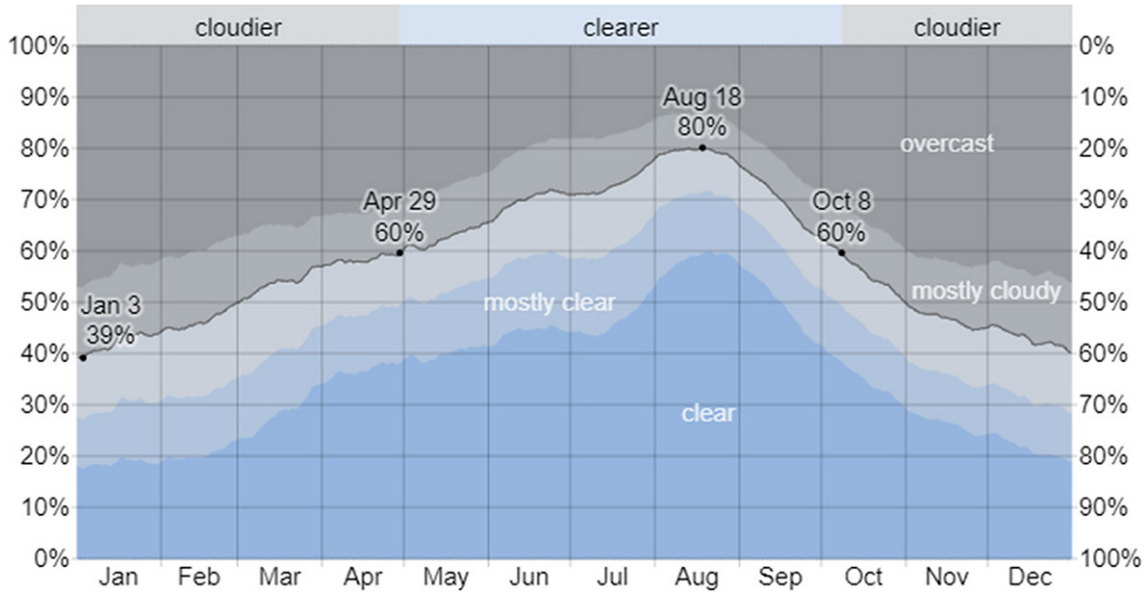

Figure 4 – Categories of cloudiness in Ushbiik

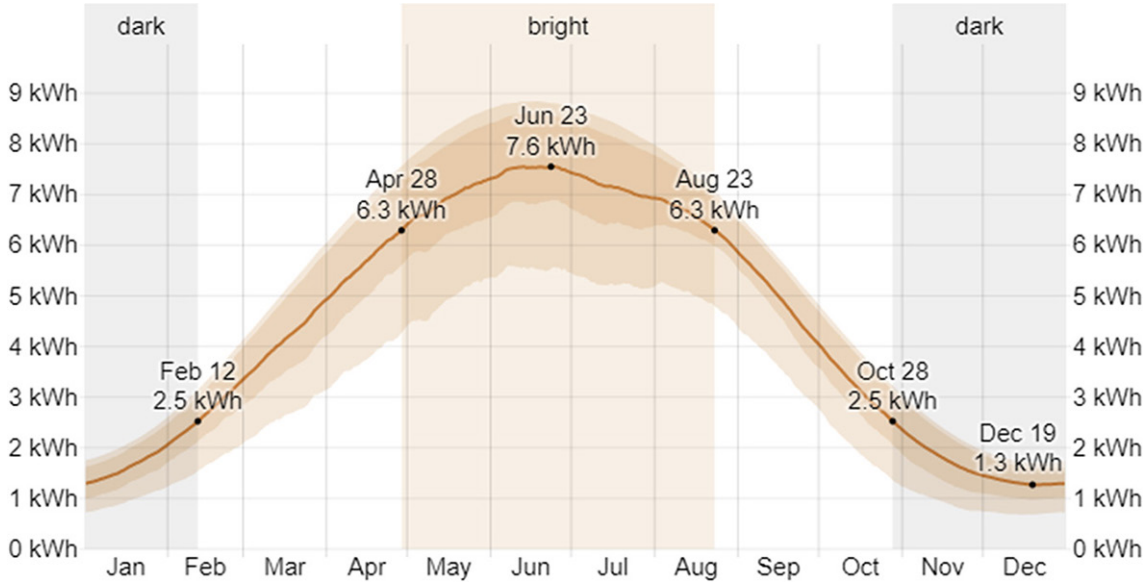

Figure 5 – Graph of the average daily incident shortwave solar energy in Ushbiik

for the development of the fuel and energy complex in the country and in the world.

The use of hybrid photo-diesel power supply systems for remote consumers on the example of the village of Ushbiik is the most optimal solution in terms of ensuring uninterrupted power supply. During the study, analyzes of the day length, the average daily incident short-wave solar energy, cloudiness, solar radiation, etc. were made. These results will be used in writing and preparing the master's thesis.

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Үшбиік ауылы мысалында шалғайдағы тұтынушыларды орталықтандырылмаған фотодизельді электрмен жабдықтау жүйесінің құрылымын оңтайландыру

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***Аңдатпа.** Бұл жұмыстың мақсаты таңдалған аумақтың елді мекенді мысалға ала отырып, Қазақстанның шалғайдағы тұтынушыларын орталықтандырылмаған фотодизельді электрмен жабдықтау жүйелерінің құрылымын енгізу және оңтайландыру мүмкіндіктерін зерттеу болып табылады. Шалғай елді мекендер мен тұтынушыларды бір жақты электрмен жабдықтау мәселелері, энергожүйе тоқтауының негізгі себептері зерттелді. Осыған орай, шалғайдағы тұтынушыларды электрмен қамтамасыз ету біздің еліміздің энергетика саласын дамытудың кезек күттірмейтін міндеті болып табылады. Бұрынғы зерттеулерге және осы тақырыпты жетілдіру тенденцияларына талдау жасалды. Таңдалған аймақтың ең жоғары кезеңдегі электр энергиясын тұтынуын есептедік және алынған деректер негізінде қолданудың тиімділігін және фотодизельді электрмен жабдықтау жүйелерінің негізгі артықшылықтарын талдадық. Шетелдік өндірушілердің тәжірибесіне сүйене отырып, фотодизельді электрмен жабдықтау жүйесіне арналған негізгі компоненттер таңдалды.*

***Кілт сөздер:** гибридті электрмен жабдықтау жүйелері, фотодизельді электрмен жабдықтау жүйесі, дизельдік электр станциясы, электр энергиясын тұтынушы, электрмен жабдықтау, энергия жүйесі.*

Оптимизация структуры децентрализованных фото-дизельных систем электроснабжения удаленных потребителей на примере села Ушбиик

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Аннотация. *Целью данной работы является изучение возможности внедрения и оптимизация структуры децентрализованных фото-дизельных систем электроснабжения удаленных потребителей Казахстана на примере выбранной местности. Изучены проблемы энергоснабжения отдаленных районов и потребителей с одностороной подачей, основные причины отключение энергосистемы. В связи с этим, электроснабжение удаленных потребителей является актуальной задачей развития энергетической отрасли нашей страны. Был проведен анализ более ранних исследовании и тенденции усовершенствования данной тематики. Провели расчет потребляемой мощности электрической энергии выбранной местности в пиковый период и на основании полученных данных, проанализировано эффективность применение и основные преимущества фото-дизельных систем электроснабжения. По опыту иностранных производителей были выбраны основные составляющие для фото-дизельной системы электроснабжения.*

Ключевые слова: *гибридные системы электроснабжения, фото-дизельная система электроснабжения, дизельная электростанция, потребитель электрической энергии, энергоснабжения, энергосистема.*

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