

## THE MAIN LOSSES OF THE UKRAINIAN ENERGY SYSTEM AS A RESULT OF MASSIVE ATTACKS BY RUSSIA

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**Abstract.** For Ukraine, which is in a state of hybrid war with the Russian Federation, the issue of effective counteraction to the consequences of massive Russian attacks on the energy system of Ukraine is vital. Therefore, the study of the state of the electric power industry after the terrorist attacks of Russian aggressors and the actions of the authorities to neutralize the damage caused by the enemy is an extremely urgent task. The purpose of the article is to analyze the state of the electric power industry after the terrorist attacks of Russian aggressors and the actions of the authorities to neutralize the damage caused by the enemy. The structural-functional method helps to identify the main elements of conflict interaction, to determine the role of each of them. In this case, we are talking about the actions of the state-terrorist regarding the massive attacks of Russians on the energy system of Ukraine, but also in the ability of the Ukrainian authorities to guarantee the stable functioning of the electricity industry in war conditions. The method of expert assessments, the essence of which is that it is experts: scientists, politicians, journalists who give professional, unbiased assessments of objective and subjective factors affecting the situation in the electricity sector. Historical - critical method, which means the study of the emergence, formation and development of objects in chronological sequence. In this case, we are talking about the study of the emergence and further development of the Ukrainian-Russian war. The main results of the research presented in the article consist in the systematization of total losses of the energy system of Ukraine during the war. The article proposes the main measures to restore the energy system of Ukraine.

**Keywords:** Ukrainian-Russian war, Ukrainian electricity industry, fuel and energy complex of Ukraine, renewable energy sources, nuclear generation and hydrogen energy.

**JEL Classification:** F47, L94, P18

**Formulas:** 0; **fig.:** 0; **tabl.:** 1; **bibl.:** 9

**Introduction.** The Ukrainian-Russian war, which has lasted for eight years, has caused great damage to the Ukrainian electricity industry. Firstly, there was a sharp drop in the use of electricity by at least 40%. Secondly, the enemy captured part of the power generating capacities, several dozens of power plants of various types were destroyed due to shelling with missiles, shells, bombs. Thirdly, the majority of CHPs and TPPs that work on coal were left without this energy raw material, because the mines are in the occupied territory.

All this negatively affects the Ukrainian economy, leads to a drop in GDP, impoverishes the Ukrainian people.

Thus, our state faces a challenge not only in ensuring national security in confronting military aggression from Russia, but also in the ability to guarantee the stable functioning of the electric power industry in the conditions of war.

The situation in the fuel and energy complex and the level of energy security that the government is able to provide is a litmus test of the maturity of public policy and the quality of public administration. The events that have been developing in Ukraine after February 24 emphasize its systemic importance.

The interests of the state, business and every citizen intersect in the fuel and energy sector. The highly sensitive social component makes it the focus of attention not only of government officials managing the economy, but also of the President of Ukraine, who in his oath pledged to "take care of the good of the Motherland and the welfare of the Ukrainian people".

And in the annual address to the Verkhovna Rada, delivered by Volodymyr Zelenskyy on December 28, the energy sector was given a special role.

"Now that the enemy has set out to destroy our energy sector, we aim to become a leader in its transformation to counter any threats - military, political, economic or even climate. We must become - and will become - a leader in building modern green energy. This will allow creating a decentralized energy system that cannot be destroyed by missile strikes," the President said. He also noted that the development of renewable energy sources, nuclear generation and hydrogen energy would strengthen the role of Ukraine in Europe.

"Restoring justice for millions of Ukrainians who suffered from the unjustified and extremely brutal Russian invasion is a matter of principle for the Ukrainian government and public.

Every day lost is additional destruction and suffering of Ukrainians at the hands of the invaders. Russia, its criminal government and citizens must be held accountable for their crimes against Ukrainians.

This can be achieved through close cooperation with our Western partners, as well as a consistent policy of collecting compensation from the aggressor. Countries that were in similar situations spent sometimes decades on collecting evidence and trials. For Ukraine, this process can last only a few years.

Recognized by the European Parliament, the Council of Europe and the NATO Parliamentary Assembly as a state sponsor of terrorism, Russia shelled Zaporizhzhya Nuclear Power Plant again, once again bringing the world to the brink of nuclear disaster. The occupiers continue to attack the civilian infrastructure of Ukraine, creating a humanitarian catastrophe and polluting the environment. Attacks by Russian drones and missiles on the objects of the Ukrainian electric power industry have become regular. The aggressor country is not deterred by holidays or the huge damage they cause to ordinary citizens who suffer from lack of electricity, heat in their homes, water supply. These actions of Russia fall under the definition of a terrorist state and will certainly be assessed by the international community.

**Literature review.** The above-mentioned problems testify to the concentration of attention of domestic researchers on the analysis of the state of the electric power industry of Ukraine after the massive Russian attacks on the energy system of

Ukraine. A significant contribution in this area was made by scientists-economists, namely: V. Grushko, Y. Korolchuk, H. Konovalova, C. Mikhailovskaya, L. Trotsenko, M. Topalov, O. Kharchenko and others.

At the same time, in today's complex domestic economic realities, a significant transformation of theoretical and methodological approaches to determining the state of the electric power industry of Ukraine during the Ukrainian-Russian war is necessary, which requires a detailed scientific study of this problem.

**Aims.** The purpose of the article is to analyze the state of the electric power industry after the terrorist attacks of Russian aggressors and the actions of the authorities to neutralize the damage caused by the enemy.

**Methods.** The structural-functional method helps to identify the main elements of conflict interaction, to determine the role of each of them. In this case, we are talking about the actions of the state-terrorist regarding the massive attacks of Russians on the energy system of Ukraine, but also in the ability of the Ukrainian authorities to guarantee the stable functioning of the electricity industry in war conditions.

The method of expert assessments, the essence of which is that it is experts: scientists, politicians, journalists who give professional, unbiased assessments of objective and subjective factors affecting the situation in the electricity sector.

Historical - critical method, which means the study of the emergence, formation and development of objects in chronological sequence. In this case, we are talking about the study of the emergence and further development of the Ukrainian-Russian war.

**Results.** Russia, having suffered painful defeats on the battlefield, cowardly and insidiously, violating all possible and impossible rules of warfare, carries out terrorist attacks on Ukrainian cities and villages, civilian critical infrastructure, energy facilities, destroys centralized drinking water supply. The purpose of the attacks is to exterminate Ukrainians by creating uninhabitable conditions.

Energy facilities have been under shelling by Russian terrorists since the first months of the war. On February 24, 2022, the aggressors seized the Chornobyl NPP. After a long resistance, the Russians seized the Zaporizhzhia NPP on March 4. ZNPP has 6 power units with a total capacity of 6000 MW and is the largest nuclear power plant in Europe.

As for CHPPs and TPPs, the situation is as follows. Due to the shelling by Russian occupants in Ukraine at least 4 thermal power plants were damaged, namely Luhansk CHP, Okhtyrka CHP, Trypillia CHP and Chernihiv CHP. Luhansk CHP is lost, Okhtyrka CHP is actually completely destroyed [1].

Zaporizhzhya thermal power plant has run out of coal, which cannot be supplied due to the temporary occupation of Enerhodar by Russians and hostilities in the South of Ukraine - the operation of the TPP is stopped.

In the hydropower sector, Ukraine has annexed the Kakhovka HPP, and the Trypillia TPP in Kyiv region was hit by Russian shells, but it is still operating.

The owner of SCM company, billionaire Rinat Akhmetov estimates the loss of wind generation of DTEK energy holding due to the Russian invasion in Ukraine at 500 MW.

Huge losses due to terrorist actions of Russians are in renewable energy sources. Let's start with solar energy. 60% of industrial solar power plants are located in the places of fierce fighting, in the southern and southeastern regions of Ukraine. This has caused huge losses from the Russian occupiers. According to preliminary data, 30-40% of solar power plants in these regions were destroyed, which is 1120-1500 MW of their capacity.

The greatest damage was caused to these facilities in Mykolaiv region. Thus, the solar park of the Solar Generation company (22 MW) was half destroyed by artillery and helicopters of the enemy. And the remaining generation cannot be used because 5.5 km of 150 kV power lines supplied to Mykolaiv were destroyed. Almost 100% of the capacities of solar power plants were destroyed in Kharkiv region.

As of January 2022, 1.2 GW of solar power plants were installed in private homes in the country, about 280 MW (24%) have been destroyed to date.

Wind energy has also been developed in Ukraine. As of January 1, 2022, the gross generation of operating wind power plants is 1673 MW. They are mainly located in Zaporizhzhia, Mykolaiv, Lviv, Odesa regions. Due to the war with Russia, 2/3 of wind generators are not working, which is 1162.5 MW of capacity, only 372.5 MW are working, mainly in Odesa and Lviv regions.

In Zaporizhzhya region, all wind farms of DTEK (Botievska - 199.88 MW, Prymorska-2 - 99.58 MW, Orlovska - 98.8 MW) are not working, except for Prymorska-1 - 99.58 MW. The 330 kV overhead power line in Melitopol cannot supply current due to the destruction of the power line. Zaporizhzhya wind power plant of LLC "Yurokap Ukraine" - 98.1 MW - is not operating in the region.

In Mykolaiv region, the turbines of the Prychornomorsky Wind Park and fourteen turbines of Wind Parks of Ukraine LLC do not work.

In Odesa region, the Pivdenne Energy WPP (76.5 MW) has stopped working, but the Dniester WPP (not fully) of Elementum Energy LLC (40 MW) and the wind park of Turkish Guris "Ovid Wind" (32.67 MW) are producing electricity.

As of early July 2022, two wind turbines belonging to different owners were destroyed.

As for bioenergy, the situation is as follows. Companies that produce electricity from biomass in Ukraine can generate 224.5 MW (119.1 MW from biomass, 105.4 MW biogas). All these enterprises are located on the territory of powerful agricultural enterprises. As of early July 2022, the Russian aggression destroyed

10-15% of installed capacities. This primarily concerns the north and east of Kharkiv region, Sumy and Chernihiv regions, Mykolaiv district, Zhytomyr city[2].

As we can see, at first, the occupants seized generating capacities and disconnected them from the United Energy System of Ukraine, hit CHPPs that produce heat and hot water, and thermal power plants in the area of active hostilities.

The enemy launched a missile attack against the power system in September, hitting high-voltage network facilities in the Kharkiv region.

In October 2022, Russia significantly increased its attacks on Ukraine's energy facilities, damaging about 40% of the country's energy infrastructure.

On October 10-11, 2022, the Russian aggressor began to use new tactics: they identified critical energy infrastructure facilities as the main target. As you know, the energy system consists of two parts: power plants that generate electricity and infrastructure for its supply. In October, the aggressor set a goal to destroy both components. First, they launched rocket and bomb attacks on switchgears, transformers and switches to disconnect the power plants from the UES of Ukraine.

Thus, on October 10-11, the racists carried out a powerful attack on high-voltage substations of "Ukrenergo", they hit these objects in the western regions, central region, south and east of Ukraine. Russian terrorists did not stop there and bombed energy facilities every day.

A big problem is that Russian power engineers advise military terrorists on which infrastructure facilities are the most vulnerable.

On October 17 and 22, the next two large-scale attacks took place. Rashists sought to destroy power plants and again high-voltage substations of "Ukrenergo". Russian barbarians used not only cruise missiles, but also Iranian drones for this purpose. On October 10, there were up to five arrivals at some facilities, and there are substations with up to 10 missiles and 2-3 drones. As a result of enemy attacks, about 30% of the power system suffered varying degrees of damage.

On October 31, 2022, due to massive shelling of critical infrastructure, Ukrenergo was forced to initiate emergency power outages. In total, 13 energy facilities were hit. After the loss of light, water supply is stopped. Water was cut off in Kharkiv and Zaporizhzhya, 80% of subscribers in Kyiv have no water supply.

In the second wave on the same day, Russian terrorists hit 10 regions with missiles and drones, where 18 objects were damaged, most of them energy facilities, as a result hundreds of settlements in seven regions of Ukraine were cut off from electricity. The consequences could have been much worse, but thanks to the professional work of air defense 44 out of more than 50 Russian missiles were shot down[3].

Kyiv Mayor Volodymyr Klitschko reported two strikes on critical infrastructure facilities in Kyiv. There was also an attack on one of the communities of the Kyiv region, according to the OVA.

Critical energy infrastructure facilities were also hit in Kharkiv, Zaporizhzhia, near the city of Svitlovodsk in Kirovohrad region and in Cherkasy region. There are problems with electricity supply in these regions.

In Cherkasy region, according to the regional authorities, two-thirds of the region has no electricity. Kharkiv city authorities reported that the subway, trams and trolleybuses are not working, but buses are running. There are also possible problems with water supply.

Due to the Russian attack, parts of Zaporizhzhia were left without electricity and in some places without water, the OVA reported. Windows in high-rise buildings, a hospital, a school, a house of culture and an infrastructure facility were blown out.

For the first time, Chernivtsi region suffered an attack on critical infrastructure. The damage to critical infrastructure as a result of the shelling was reported by the head of the Chernivtsi Regional Military Administration Ruslan Zaporanyuk.

In Bukovina, Russians hit the Dniester hydroelectric power station, the Moldovan authorities reported. There, in the morning of October 31, a Russian missile fell in the village of Naslavcha, Ocnita district in the north of the country, the local Interior Ministry reported.

The ministry noted that the missile was shot down by the Ukrainian air defense system and fell on the northern edge of the village of Naslavcha, located on the border with Ukraine.

The head of the Dnipropetrovs'k Regional Military Administration Valentyn Reznichenko reported that energy infrastructure facilities in Dnipro and Pavlohrad were hit. According to him, there are serious destructions, all services are working[4].

Local emergency power outages continue in Kyiv, Zaporizhzhya, Dnipropetrovsk and Kharkiv regions. Today, as in previous weeks, it is important that all Ukrainians consciously consume energy and reduce the load on the grid.

Since February 24, Russians have struck at energy facilities 85 times. Two out of three strikes occurred in the last two weeks of the war. The enemy uses air-, sea- and land-based cruise missiles, ballistic missiles, anti-aircraft guided missiles and Iranian Shahed-136 drones.

Donetsk, Sumy, Dnipropetrovsk and Lviv regions suffered the most. Only Zakarpattia, Chernivtsi and Ternopil regions avoided the attacks. The purpose of the attacks is to destroy Ukrainians by creating uninhabitable conditions.

In the conditions of Russian terror in the electric power system of Ukraine, it is extremely important that in March the power system of Ukraine was synchronized with the network of continental Europe ENTSO-E. This made it possible to start commercial export of electricity to the EU countries on June 30. In September this year, it was recorded that the export of current ranks second in ensuring export revenues of the state in the conditions of war.

However, since October 11, Ukraine was forced to suspend electricity exports to the EU to stabilize its own energy system as a result of rocket attacks on the energy infrastructure of Ukraine. It should be noted that the technical capabilities of grid synchronization also work in the opposite direction, if it happens that Ukraine needs to import electricity from the EU [5].

Ukraine's membership in ENTSO-E has created conditions for assistance from the transmission system operators of Germany, Belgium, Denmark, Poland, Slovakia, and Lithuania. Ukrainian power engineers receive equipment and materials from these countries. For example, this is the wire that is most needed to restore the power grid. These are also uninterruptible power supplies, floodlights for the work of crews at night. "Ukrenergo is negotiating with European partners to replenish the transformer park, relay protection equipment, switches and disconnectors. Table No.1 is provided below: "How allies help Ukraine in connection with the destruction of power facilities (as of 1.12.2022)".

**Table 1. How allies help Ukraine in connection with the destruction of energy facilities (as of 1.12.2022)**

Country	Financing of repair (mln usd)	Generators	Transformers
Great Britain	6		
Israel		20	
Spain		30	
Canada	48,2		
Latvia		84	
Lithuania	7,2	160	114
South Korea		20	
Germany	59	135	
Netherlands	73		
USA	108	1000	
Switzerland	100		
Czech Republic	1		
Japan	3		
European Union		40	202
Taiwan		20	

Source: <https://www.slovoidilo.ua/2022/12/01/infografika/suspilstvo/vidnovlennya-enerhetychnoyi-infrastruktury-ukrayiny-chym-dopomahayut-soyuznyky>

European Union Commissioner for Energy Kadri Simson arrived in Kyiv on November 1. She arrived in the Ukrainian capital the day after a massive Russian missile attack, during which critical infrastructure of Ukraine was shelled. The attacks left much of Kyiv without electricity and water. Simson said she arrived in Kyiv to "help scale up support for Ukraine's energy sector." [6]

On November 1, 2022, President Volodymyr Zelenskyy met with European Union Commissioner for Energy Kadri Simson and discussed the restoration of Ukrainian energy infrastructure after Russian strikes and the stabilization of Ukraine's energy grid. In her turn, the Commissioner stated that we have 25.5 million euros ready to ensure the urgent needs and appropriate supplies literally during this meeting. During the escalation, the Russian attacks on the energy system, we need to support Ukraine. I have already seen this destruction with my own eyes, so I will do everything possible to increase the financial, technical, as well as practical assistance that should come from the EU, our institutions, but also from our international partners and private donors.

At the same time, Zelenskyy drew attention to the expediency of creating a platform to support the Ukrainian economy, in particular the energy sector, such as the Contact Group in the Ramstein format [7].

On November 4, 2022, US Secretary of State Anthony Blinken announced that the G7 countries had agreed on a new format to help Ukraine, whose energy infrastructure is suffering from Russian attacks. The new coordination mechanism will be similar to the "Ramstein format", which provides military support to Ukraine.

It is not only about restoring damaged infrastructure, but also about strengthening its resilience. To do this, it is necessary to understand what Ukraine's needs are and what each state can offer on its part, taking into account the available resources. Ukraine appealed to partners to supply equipment for repairs. The call was answered by 12 states, as well as G7 countries [8].

Already in early November, 17 European Union states decided to send Ukraine 500 electric generators. Among the countries that provided such assistance are Slovenia, Slovakia, Ireland, Austria, Sweden, Spain, Germany, Italy, Denmark, Finland, Estonia, Belgium, Bulgaria, Luxembourg, Cyprus, Poland and France[9].

At the same time, Ukraine has opportunities to increase electricity production. It is primarily about renewable energy sources. To do this, the Verkhovna Rada should adopt a law to support investors who want to build wind power plants, as well as small hydropower facilities in the western regions: Transcarpathian, Ivano-Frankivsk and Lviv regions. This law will create conditions for the commissioning of "green" energy facilities, thanks to which Ukraine would receive at least 500 MW of additional capacity in a fairly short period of time. Every 100 MW of built "green" capacities means UAH 1 billion of revenues for the state.

Already on the night of December 31, 2022 to January 1, 2023, Russian aggressors struck again at civilian infrastructure in different regions of Ukraine. Residential buildings, a hotel, a shop, a place of celebration were damaged. There are dead and wounded. However, as stated by Prime Minister Shmyhal, the Russians want to intimidate and leave Ukrainians in the dark on New Year's Eve, causing as much damage to civilian infrastructure as possible. Despite this, the power system remains stable. All services are working to eliminate the consequences of the attacks.

**Discussion.** The actions of the aggressor country to destroy the infrastructure of the electric power industry of Ukraine receive a sharp negative assessment of the leading countries of the world, international organizations. However, there are countries whose leadership pretends that nothing extraordinary happened in the Ukrainian-Russian war and Russian terrorists do not deserve tougher sanctions and appropriate punishment. This puts before the Ukrainian diplomacy, scientific community the task of finding the reasons for such a position of these countries and ways to influence them in order to change their anti-Ukrainian position.

**Conclusion.** Russia will continue its energy terror against Ukraine and energy pressure on the European Union. Ukrainian people will continue to suffer from interruptions in the supply of electricity, water and heat. In the conditions of winter, which will soon come to the country, these difficulties will only increase. Therefore, it depends on the balanced actions of the Verkhovna Rada, the Cabinet of Ministers, resilience and preparedness of the Ukrainian people how we will survive the winter this year.

**Author contributions.** The authors contributed equally.

**Disclosure statement.** The authors do not have any conflict of interest.

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