Mastering Civil Defence in Times of Conflict

Collective Monograph

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НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ЦИВІЛЬНОГО ЗАХИСТУ УКРАЇНИ

NATIONAL UNIVERSITY OF CIVIL DEFENCE OF UKRAINE

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CONTENTS

LIST OF ABBREVIATIONS

AAD	Anti-Aircraft Defence
AFU	Armed Forces of Ukraine
AFPS	Automated Fare Payment Systems
ATTT	Automation and Telecontrol of Train Traffic
CF	Charitable Fund
CFYSS	Centres of Family and Youth Social Services
CPU	Communication Point of the Unit (fire department)
CS	Chief of Staff
CZ	Combat Zone
DPS	Diesel Power Station
EO	Explosive Objects
ES	Emergency Situation
ESS	Substation
FES	Fire extinguishing substances
FRU	Fire and Rescue Units
FRV	Fire and Rescue Vehicle
HAPP	Hydro-Accumulating Power Plant
HFE	Head of Fire Extinguishing
HPS	Hydroelectric Power Station
HR	Head of the Rear
ID	Input Device
IDD	Input and Distribution Device
IHE	Institution of Higher Education
IP	Iodine Prophylaxis (iodine blocking of the thyroid gland)
MDB	Main Distribution Board
MSOMS	Metro Station Operation Management System
NPP	Nuclear Power Plants
OCC	Operational Coordination Centre
OP	Operative Precincts
ORSCP	Operational and Rescue Service of Civil Protection
RCOP	Radiation and Chemical Observation Posts
RII	Radioactive Isotopes of Iodine
SES	State Emergency Service
SDPP	State District Power Plant
SwG	Switchgear
TD	Territorial Defence
TPP	Thermal Power Plant
UAVs	Unmanned Aerial Vehicles
UCPS	Unit of Continuous Power Supply
WOOP	Warehouses of Oil and Oil products

INTRODUCTION

The hostilities, which originated in eastern Ukraine in 2014, escalated into a full-scale war on February 24, 2022, following the invasion by the Russian Federation. Hundreds of cities and towns across nearly all state regions were targeted by rocket and artillery fire. The most intense fighting occurred in Luhansk, Donetsk, Kharkiv, Sumy, Chernihiv, Kyiv, Kherson, Mykolaiv, and Odesa regions. Over 5 million Ukrainian citizens were compelled to evacuate to secure locations in western Ukraine, Europe, and beyond. On February 24, 2022, the President of Ukraine, Volodymyr Zelensky, signed Decree No. 64/2022, "On the introduction of Martial Law in Ukraine".

The Ukrainian civil protection system had to work in the new realities. After all, rescuers, by their vocation, are always close to those who need help and provide salvation to people regardless of the circumstances around them. The city of Kharkiv was in the active combat zone from the first hours of the invasion and the beginning of hostilities, and employees of the National University of Civil Defence of Ukraine, like all the rescuers of the country, accepted the challenge and started actively rearranging their work in conditions of constant shelling.

The dangerous working conditions of rescuers demanded new, unique approaches to solving Civil Defence problems during martial law. The main task is the rescuers' safety when facing challenges during firefighting at critical infrastructure facilities. In the zone, chemically dangerous objects and radioactive substances are located during hostilities. In addition, the potential threat of using chemical or nuclear weapons has significantly increased. Of course, the entire area of hostilities, which amounts to hundreds of thousands of square kilometres, has been polluted by various explosive objects, so the main work in the liberated territories is demining and removing flammable objects. The enemy's powerful strikes on the energy infrastructure have led to large-scale blackouts throughout the country, with the consequences of which we constantly have to fight. Fortunately, volunteer organisations have become widespread in such difficult conditions, supporting all sections of the population, from the military at the front to babies in hospitals. The misfortunes experienced by millions of people could not leave an imprint on their psychological health, which will require a long rehabilitation period for many years to come. Indeed, working in such difficult conditions also harms the rescuers' morale, and professional work with each individual can reduce the adverse effects and internal reserves.

Unique experiences of rescuers have been compiled in this collective monograph, which focuses on the organisation of Civil Defence and the protection of the population amidst hostilities. All the materials presented herein are the outcomes of collecting, processing, and analysing real-life practical interventions by various rescue services and university personnel operating within conflict zones in Ukraine. Weaknesses have been scrutinised, accompanied by recommendations to enhance the organisational aspects of certain activities.

This monograph is intended for a broad audience of Civil Defence specialists worldwide, united by a commitment to ensuring the safety of their fellow citizens.

CHAPTER 5

FUNCTIONING OF THE CIVIL PROTECTION SYSTEM UNDER BLACKOUT CONDITIONS

An accident in the power supply system is a violation of normal mode of the entire energy system or a significant part of the energy system, associated with damage to equipment, temporary unacceptable deterioration of electricity quality, accompanied by an interruption in the supply of electricity to consumers. Accidents in energy systems are often called the word “blackout” [1].

5.1 World history of blackouts in the 21st century

The world history of blackouts in the 21st century is summarized in Table 5.1

Table 5.1. History of blackouts of the civilized world in the 21st century

Date	**Country**	**Cause and effect**
02.01.2001	India	As a result of an accident at a power plant in Uttar (Pradesh) more than 200 million residents of the north of the country remained without electricity
18.01.2001	USA	1 million Californians living in and around San Francisco were left without electricity
06.2001	Nigeria	Between 30 and 50 million residents lived without electricity for several days as a result of a power system failure in the east of the country
24.11.2002	Argentina	In the capital of Argentina, Buenos Aires, there was an accident on a high voltage line. About 2 million people remained without electricity

03.02.2003	Algeria	The whole of Algeria with a population of 32 million people was left without electricity for several hours due to an accident at the central power plant
22.07.2003	Spain	More than 350,000 residents of Barcelona and the Balearic Islands were left without electricity after an accident caused by an overload
22.07÷14.08. 2003 Big Blackout 2003	USA, Canada	About 10 million people in Canada (about a third of the population) and 40 million in the USA were left without electricity. Many airports closed, including Pearson International Airport in Toronto and all airports in New York. In many cities, including Toronto and New York, the subway stopped working. Passengers stuck in the subway had to be evacuated. There were water outages in some cities, in particular in Detroit. Cell phones worked very poorly, with major outages, but landlines continued to function. The reasons for the blackout are as follows: due to high electricity consumption, power lines in Cleveland, Ohio heated up, sagged (due to thermal expansion of the wires) and touched trees (which were not trimmed in time). Due to an error in the computer system, as well as the actions of personnel, other control centres were not notified in time. There was a cascading shutdown of about 100 other power plants.
18.08.2003	Georgia	The whole of Georgia remained without electricity. The reason was the emergency shutdown of Inguri HPP - the country's largest HPP (produces almost half of the electricity). After that, the entire energy system of Georgia was turned off. There was no electricity even at life support facilities, the subway stopped working, tens of thousands of passengers were stuck in train cars and at stations. Water supply has stopped in most Georgian cities. The central TV tower in Tbilisi did not work for 20 minutes.
28.08.2003	Great Britain	In the capital of Great Britain, London and some areas in the southeast of the country, a large-scale power outage occurred in the evening. Approximately two-thirds of the metro and part of the trams stopped running, streetlights and signal lamps in the areas of power failure went out, chaos was observed in city transport. The reason for the power outage was an accident in the transformer system. There were about 250,000 people in the London subway who were evacuated from trains that stopped in the tunnels. Electricity supply was restored 34 minutes after its outage
23.09.2003	Sweden, Denmark	The storm knocked out power lines, causing power outages in southern Sweden and eastern Denmark. 5 million people remained without electricity for a whole day

28.09.2003	Italy	The emergency power outage affected the entire territory of Italy, with the exception of the islands of Sardinia and Elba, for 12 hours, as well as parts of Switzerland in the Geneva area for 3 hours. The falling tree caused a blackout on the Mettlen-Livorno transmission line, which stretches from Switzerland to Italy. This caused a 110% overload on the second Swiss line, Sils-Soazza. 20 minutes after the events began, the Italian side reduced the volume of electricity imports due to an increase in domestic production. But this did not sufficiently relieve the San Bernardino line, which failed. The outage of this line caused a series of cascading outages on the remaining Swiss lines. The complete loss of the Swiss lines caused overloading of the power transmission lines stretching to Italy from France. The French lines were out of action. In the next few seconds, the lines going to Italy from Austria and Slovenia were de-energized. After a series of power outages connecting Italy to the continent, generators in northern Italy also failed due to excessive load, leading to a complete blackout. 56 million of consumers remained without electricity. The subway stopped working, 110 trains stopped on the railways. As a result of the power outage, four people died - one man and three women. A man was hit by a car at an unlit intersection, a woman suffered multiple burns when a candlestick fell on her; two more elderly Italian women fell down the stairs
07.11.2003	Chile	As a result of the heat, an accident occurred at the central power plant in Chile. 600,000 residents of the city of Santiago remained without electricity for four hours
22.01.2004	Turkey	The entire European part of Istanbul was without electricity due to the snowstorm
12.07.2004	Greece	As a result of the accident at the power plant, 6 million residents of the city of Athens and the southern part of the country remained without electricity for two hours.
09-10.08.2004	Jordan	The power supply system of the region with a population of about 5.8 million people was completely paralyzed for a period of up to three hours
22.11.2004	Poland	An accident in the power system in Warsaw. In the evening, as a result of a sudden power outage, three districts of the city of Warsaw ("Mokotów", "Polyuwa" and "Wola"), a quarter of the city's where 1.5 million people live, were left without electricity. Due to the lack of power supply, Frederic Chopin International Airport was closed for an hour and a half, as a result of which at least 12 planes were diverted to other airports, several flights were delayed. According to the city's Fire Service, passengers of the capital metro were not injured. During the blackout, by a happy coincidence, all the trains ended up in subway stations and not in tunnels
23.01.2005	Canada	Due to the flood, the city of Toronto remained without electricity for about 12 hours

14.08.2005	Japan	The reason was a break in the high-voltage cable. The lifting crane, which was on the ship, broke one of the main power transmission lines stretched over the Edogawa River. More than a million apartments in Tokyo remained without electricity, as well as in the cities of Kawasaki and Yokohama. In Tokyo, the subway stopped for 30 minutes, traffic was completely stopped on several lines of ground trains. About three hundred traffic lights went out on the capital's roads. The fire department received more than 20 calls from people stuck in elevators. The ATMs were turned off. The attractions of Tokyo Disneyland remained without electricity
04.11.2006	Germany	When the passenger liner, built at the shipyards in the city of Papenburg, entered the sea along the Erms River, a scheduled disconnection of the 380-KIlovolt line was carried out for the passage of the liner under it. However, during the redistribution of electricity flows, the automatic protection system of one of the neighboring lines was triggered, which caused a wave of blackouts in Germany, the Benelux countries, France, Spain, Portugal, Italy, Morocco, Austria and Croatia
09.11.2009	TajiKIstan	As a result of the accident on the "Nurek - Regar" transmission line, almost all of Tajikistan's hydroelectric power plants, including the country's largest Nurek hydroelectric power plant, stopped producing power, which led to the disruption of electricity supply to about 70% of the territory of Tajikistan. The accident occurred at 4:35 a.m. local time and, according to the press secretary of the "Barqi Tojik", was eliminated in an hour and a half. Specialists of " Barqi Tojik " associate the accident with the autonomous operation of the Tajik power system outside the United Power System of Central Asia, due to the lack of transit electricity from Uzbekistan and Turkmenistan
10.11.2009	Brazil	According to the main version, the cause of the event was the damage of the LEP, connecting the dam of "Itaipu" with the Brazilian power system, which made it impossible to release the power of the NPP. Power outages affected more than 50 million people living in Brazil; there were also power outages in Uruguay. The power outage occurred at 8:15 p.m. local time, power was restored at 0:37 a.m. on November 11
31.07.2012	India	The power crisis began after four northern states - Rajasthan, Haryana, Punjab and Uttar Pradesh - exceeded the power consumption quota. After that, the outages spread to neighboring areas. The problems in the power supply system began around 2:30 a.m. local time. Hospitals and schools remained without electricity. More than 600 million people in India experienced problems in energy supply, which affected 19 states in the north and east of the country. The Northern, Eastern and North-Eastern power supply system's worked with interruptions. Electricity supply in Delhi has fallen from 4,000 MW to 40 MW. All six lines of the Delhi Metro were not working, passengers were taken out of the stations. The system of city traffic lights worked with violations. More than 500 railway depots were suspended in northern India. By the morning of the second day, it was possible to completely restore the power supply of the northern and western regions of the country

24.09.2012	Kazakhstan	In the city of Almaty, there was an emergency disconnection of all 220 kV connections at the “Almaty-500” substation. The reason was a short circuit on the RU-220 bus section, which arose due to erroneous actions of the personnel. As a result, the entire city and the Almaty region were left without electricity, including such large facilities as the subway and the city’s airport
20.11-08.12.2015	Ukraine	As a result of the undermining of power transmission line supports from mainland Ukraine to the Autonomous Republic of Crimea, energy supply to the peninsula was completely stopped. For two weeks, the activists prevented the restoration of the pylons and the restoration of electricity supply to Crimea. A state of emergency was introduced in Crimea and fan shutdowns began
03.07.2018	Azerbaijan	The cause of the accident was the failure of a transformer on one of substations of the Azerbaijan TPP, as a result of which an opening occurred, which, in turn, disrupted the normal operation of the entire power plant. These problems were caused by abnormal heat and increased electricity consumption. As a result of the accident, the power supply was stopped in 39 cities and regions of Azerbaijan, including Baku and Ganja. The operation mode of the enterprises of the State Oil Company of Azerbaijan (SOCAR) was violated: the operation mode of land industries was violated, the compressor stations of the Gas Export Administration, as well as the Baku Refinery, the enterprises of the production association “Azerkhimiya” and the Azerbaijan Gas Processing Plant were stopped in emergency mode. JSC “Azerenerzhy” appealed to neighboring countries about the import of electricity. Azerbaijan temporarily suspended exports electricity to Iran
09.08.2019	Great Britain	A massive power outage occurred in the evening in some areas of London and south-east Britain due to the failure of the country’s national energy system. The company “Transport for London”, which operates the transport system of the British capital, reported that the bankruptcy affected the work of street lighting and traffic lights, and also caused disruptions in the work of rail transport. National Rail reported that trains on some lines were briefly stopped due to a power outage, but power was later restored. The interruption affected railway lines operated by Thameslink, Southern and Gatwick Express, as well as some London Underground lines
09.01.2021	PaKIstan	Power outages across the country (114 cities) were caused by a sudden drop in frequency in the power supply system
25.01.2022	UzbeKIstan, Kyrgyzstan, Kazakhstan	As a result of a significant emergency imbalance in the power system of Central Asia (Uzbekistan, Kyrgyzstan), there was an increase in the power transit capacity of 500 kV “North-East-South of Kazakhstan”

28.09.2022	Cuba	Cuba's power generation system completely shut down due to Hurricane Ian. A tropical hurricane passed through Cuba on the night of September 27. Wind gusts reached 123 km/h. Generation in the energy system is zero (there is no energy supply throughout the country). The failure was detected in the west, in the central part and in the east
Starting from 10.10.2022	Ukraine	Blackouts in various regions of Ukraine caused by a full-scale military attack by the Russian Federation

The analysis of the data presented in Table 5.1 shows that military actions are not the main cause of blackouts.

On February 24, 2022, at 3:40 a.m., an open military attack by the Russian Federation on Ukraine began. Campaign strikes have begun throughout the territory of Ukraine. Russian troops invaded Ukraine near Kharkiv, Kherson, Chernihiv, and Sumy, entering from Russia, Belarus, and Crimea, which was temporarily occupied by Russia in 2014.

After the successful September counteroffensive of the Armed Forces of Ukraine in the Kharkiv region, the systematic destruction of Ukraine's energy system by the Russian Federation began on October 10, 2022. The longest blackouts occurred after massive shelling of Ukraine on October 10, October 31, November 15, and November 23, 2022 [2-4].

On October 10, 2022, at approximately 8:15 a.m., Russian forces launched the largest missile attack on the entire territory of Ukraine since the start of the full-scale invasion [about 100 missiles and Unmanned Aerial Vehicles (UAVs) were launched]. The missile attack is associated with the September failures of the Russian occupying forces at the front and the damage to the Kerch bridge on October 8, 2022. Missile launches were carried out in several waves from the regions of the Black and Caspian seas, including Tu-95MS and Tu-22M3 aircraft. 84 missiles were used in the strikes. Air Defence Forces managed to shoot down 43 missiles. Russia used Kh-101, Kh-555, Kalibr, Iskander, S-300 and Tornado missiles. Russia also used 24 UAVs, of which 13 were Iranian "Shahed-136" from the territory of Belarus and Crimea. Three cruise missiles fired from the western part of Crimea violated the airspace of Moldova. As of 11 a.m. on October 10, 11 important infrastructure facilities in 8 regions and the city of Kyiv were damaged as a result of the strikes. Some regions were cut off. In total, on October 10 and during less intense shelling on the following two days, 28 objects of Ukraine's energy infrastructure were damaged by missile strikes.

In Kyiv, hits were recorded in 4 districts of the city: Shevchenkivskyi, Sviatoshynskyi, Holosiivskyi and Desnyanskyi. As a result of the impact, 5 objects of critical infrastructure were damaged. All metro lines were stopped in the city.

Only in the afternoon, the Syretsko-Pecherska line of the Kyiv Metro, from the Syrets station to the Chrevyn Khutir station, resumed traffic. Damage to critical infrastructure led to the introduction of temporary restrictions on the supply of electricity to consumers (fan outages).

Fig. 5.1. Consequences of the rocket fire in Kyiv on October 15, 2022

Russia launched 15 missiles in the Lviv region, some were shot down by air defence forces, others damaged energy infrastructure facilities. According to the statement of the deputy mayor of Lviv, Andriy Moskalenko, as of 2:20 p.m., approximately 90% of the city's electricity was cut off, and the movement of trams and trolleybuses was temporarily suspended. Also, 80% of the traffic lights do not work. By 11:00 p.m., electricity was restored in the city. A total of four electric substations were destroyed in the Lviv region after the missile attacks on October 10 and 11, which not only supplied the region, but also exported energy abroad. Moreover, two of them were hit again on October 11.

At least 3 strikes were recorded on Kharkiv energy infrastructure facilities. In some areas, water and electricity have disappeared.

As a result of the shooting on the evening of October 10, 1307 people were killed.

On October 27, 2022, Russian military personnel struck critical infrastructure facilities in the Kyiv region, causing an even greater shortage of electric power than on October 10, 2022. Power grid operators were forced to introduce longer emergency consumer disconnections in the city.

On October 31, 2022, the Russian military carried out several waves of missile attacks on objects of critical infrastructure of Ukraine.

A total of 78 missiles and UAVs were launched. 55 Kh-101 cruise missiles and one Kh-59 cruise missile were fired from the Tu-95 and Tu-160 strategic aviation missile-carrying aircraft from the north of the Caspian Sea and from the Volgodonsk region (Rostov region); 44 cruise missiles were destroyed by air defence forces and means; 22 missiles from the S-300 complex were also struck, and 5 UAVs were used. Strikes by Russian missiles were recorded in Kyiv, Kirovohrad, Zaporizhzhia, Chernivtsi, Cherkasy, Kharkiv regions, and Vinnytsia region.

As a result of the attacks, 18 (mainly energy-related) facilities in 10 oblasts were damaged; power was cut off to railway sections as well as hundreds of settlements in seven oblasts of Ukraine. Rocket attacks were carried out on the Dnipro Hydroelectric Power Station (HPP), the Dniester Hydroelectric Power Station and the Kremenchuk Hydroelectric Power Station. As a result of the strikes in critical infrastructure in the Kyiv region, around 80% of consumers in the city of Kyiv were left without water and power outages were experienced.

Cruise missiles violated the airspace of Moldova. Debris of one downed rocket fell near the Dniester hydroelectric power plant, windows were blown out in many houses. On the same day, the Ministry of Foreign Affairs of Moldova summoned the Russian Ambassador and declared one employee "persona non grata".

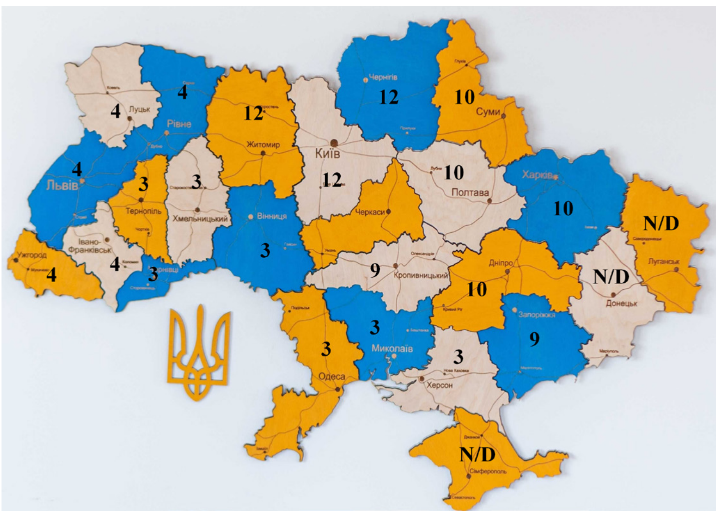

Fig. 5.2. The intensity of emergency power outages in Ukraine due to massive shelling of infrastructure from October 10 to November 3, 2022 [according to (5)]

According to data [5] in Ukraine, from October 10 to November 3, the northern and central regions, in particular, Zhytomyr, Chernihiv, Cherkasy, Kyiv oblasts, as well as Kyiv itself, were most affected by emergency power outages (excluding stabilization ones). It is noted that, in accordance with the data of "Ukrenergo" - the regional energy and military administrations - the Sumy, Kharkiv, Poltava, Dnipropetrovsk, Kirovohrad and Zaporizhia regions also suffered significant losses from emergency shutdowns. It is noted that the eastern and western regions of Ukraine, in particular Kherson, Mykolaiv, Odesa, Vinnytsia, Khmelnytskyi, Ternopil, and Chernivtsi regions, were the least affected.

On November 5, 2022, the Russian military carried out another massive shelling of the critical infrastructure of Ukraine which, in terms of the number of missiles fired - 96 air and sea-based cruise missiles X-101, X-555, "Kalibr" , and guided air missiles X-59 - surpassed the shelling on October 10 with 84 pcs.

In addition, in the morning four strikes were made from C-300 complex on the outskirts of Zaporizhzhya, and during mass shooting with cruise missiles, six more strikes from P-300 were launched in Kharkiv and Chuguev district. The Ukrainian anti-aircraft forces managed to shoot down 75 of 96 launched cruise and sea-based missiles (X-101, X-555, "Kalibr"), two controlled aircraft missiles X-59, as well as 10 submarines of Iranian production "Shamed-136/131", one UAZO "Orion" and one "Orlan-10".

As a result of the attack, 15 energy objects were damaged and over 7 million subscribers were disconnected from power consumption. Attacks on the energy system of Ukraine on November 15 caused a breakdown in the operation of the high-voltage line Vulcanesti- Isakcha - MGRES, which supplies electricity from Romania to Moldova, led to temporary loss of power supply to consumers of electricity in Moldova. The impact on energy infrastructure has affected the operation of nuclear power plants. Thus, the IAEA on the basis of the information received from the Ukrainian authorities, reported that Khmelnitsky NPP lost full access to the electricity network and temporarily switched to standby power supply from diesel generators. Both reactors had to be stopped. Rivne NPP lost communication with one of the 750 kV transmission lines. It was possible to reduce the power of the station, one of the four units was automatically switched off.

As of November 16, Kyiv Oblast, Kyiv, Ivano-Frankivsk, Rivne, Odesa, Cherkasy, Chernivtsi and Chernihiv regions have fully restored energy supplies; Lviv, Ternopil, Volyn, Khmelnytsky and Kharkiv regions – by 95%, Ternopil regions – by 90%.

The Zhytomyr and Sumy regions continued to work on reconstruction electricity supply.

On November 23, 2022, at about 15:00, Russian Federation once again caused a massive missile attack on critical objects infrastructure of Ukraine. Being unable to overcome the Armed Forces of Ukraine, the enemy is waging war against peaceful citizens, power plants, medical institutions, etc.: 67 launches of cruise missiles (X-101, X-555) and sea bases ("Kalibr"), as well as UAVs were carried out.

By the forces of the UPO of Ukraine 51 missile cruise rockets and 5 UAVs "Lancet" were destroyed; 30 rockets were fired at the city of Kiev alone, 20 of which were destroyed.

As a result of the attack, the longest blackout occurred during the entire war. All NPPs of Ukraine stopped working. At 24:00 on November 23, 11 regions of Ukraine were without electricity supply. The energy system of Ukraine managed to be unified only around 4:00 a.m. on November 24.

5.2 General information on the production and supply of electric energy to consumers

Electricity supply is called provision of consumers electric energy [6].

A consumer of electrical energy is an electrical energy receiver (electrical receiver) or a group of electronic receivers, united by a technological process, located in a certain territory.

An electrical energy receiver is an apparatus, unit, mechanism designed to convert electrical energy into another type of energy.

Receivers of electrical energy are divided into power (in particular, electric motors), lighting and special (civilian purpose, located in explosive and fire-hazardous zones, electrothermal, electric welding, etc.).

Electric energy is produced at power stations and is transmitted through electric lines to consumers.

A power plant is a combination of installations, equipment and apparatus used for the direct generation of electricity by converting other types of energy, as well as the necessary facilities and buildings located on a certain territory.

More than half of electricity in Ukraine is produced at Nuclear Power Plants (NPP). The rest of the electric energy is produced at thermal power plants (about 35%), hydro- and hydro-vacuum power plants (about 5%) and non-conventional (alternative) power plants (about 7%).

Nuclear Power Plant (NPP) is a complex of technical facilities intended for the production of electric energy by means of the use of energy allocated in the controlled nuclear reaction. The first Nuclear Power Plant built in Ukraine is the Chernobyl NPP, the first power unit of which was put into operation in 1977. The Chernobyl NPP ceased its work on December 15, 2000. In Ukraine there are four nuclear power plants – Zaporozhskaya (the largest in Europe, generates the fifth part of the annual energy production of Ukraine and half of the production of all Ukrainian power plants), Yuzhno-Ukrainska, Rivne (originally called Western Ukrainian) and Khmelnytskyi.

Thermal Power Plant (TPP) is a power plant that produces electricity by converting the chemical energy of fuel into mechanical energy to rotate the shaft of the electric generator. They allocate boiler-turbine, gas-turbine and steam-gas TPPs. Boiler turbines TPPs are divided into condensing power plants (DRES) and thermal power plants (TPPs). In Ukraine, the first Central TPP of the common use has started to operate in Kyiv City in December 1890. The electric station provided a current for lighting the city theater, Khreshchatyk Street and private houses. It was located in a stone building on Teatralna Square, where the National Opera of Ukraine named after Taras Shevchenko is located now. The power plant had an insulated boiler house, machine compartment and distribution unit. Three steam boilers were installed in the boiler house, which worked on wood. Water came from the city water. The boilers produced steam for three dual-cylinder steam engines of 44,1 kW each. These machines were driven in motion dynamometer Siemens. In addition, for power of 14 arc lanterns, installed on the street Khreshchatyk, two dynamometers with power of steam machines, power of 14,7 kW were allocated. The Power Plant was about 110,3 kW. The largest TPPs of Ukraine are Burshtyn, Vugleghirska, Dobrotvirska, Zmiivska, Kryvorizka, Kurakhivska, Myronivska, Prydniprovska, *Starobeshievska,* Trypilska.

State District Power Plant (SDPP) is a thermal condensing power plant that produces only electrical energy. Shterovska *SDPP*, located in the village of Shtergres (today Miusynsk, Luhansk region), is considered the first *SDPP* built in Ukraine. Construction of the Power Plant began in 1922, the first generator was launched on October 8, 1926, the plant was fully commissioned in 1931, and closed in 1983. The initial installed capacity of the power plant was 157 MW. Worked on anthracite. Over time, the term " *SDPP* " lost its original meaning ("district") and in the modern sense means a condensing power plant of large capacity (thousands of MW) operating in a combined power system along with other large power plants.

Thermal Power Plant (TPP) is a type of power plant that produces not only electrical energy but is also a source of thermal energy in centralized heat supply systems (in the form of steam and hot water) to provide heating and hot water supply for residential and industrial objects. As a rule, the *TPP* works according to the schedule, that is, the production of electrical energy depends on the production of thermal energy.

Gas Turbine Thermal Power Plant is a modern high-tech installation that generates electricity and thermal energy. It is based on one or more gas turbine engines mechanically connected to the electric generator and integrated control system in a single energy complex. In the gas turbine plant, the gas-like products of fuel combustion are turned. Both natural gas and oil industry products (oil, diesel fuel) can serve as fuel. On one shaft with a turbine there is a generator, which by means of rotation of the rotor produces electric energy.

Steam-Gas Thermal Power Station is a station for the production of thermal and electrical energy. It differs from the Gas Turbine Thermal Power Plant by its increased efficiency. The steam-gas unit consists of two separate units: gas turbine and steam power. The first generator is connected to the gas turbine unit. Passing through the gas turbine unit, combustion products give it only a part of their energy and at the outlet of the gas turbine have a sufficiently high temperature. From leaving the gas bin, the products of combustion get into the boiler-recovery steam-power unit, where the water vapor is heated. The temperature of the combustion products is sufficient to bring the steam to the condition required for the rotation of the steam turbine (temperature about +500 °C and pressure 80 kPa). A second generator is connected to the steam turbine.

Hydroelectric Power Station is a power plant that uses water flow energy as an energy source. It is usually built on rivers by constructing dams and reservoirs. The first Hydroelectric Power Station in Ukraine can be considered the one built in 1890 by Count Schönborn in the village of Kolchyno (near Mukacheve, Zakarpattia) on the Vyznytsia River. The station had a capacity of 200 kW and operated until 1961. The most powerful stations of Ukraine include the Dnipro cascade- that is, Kyiv, Kaniv, Kremenchutsk, Serednodniprovska (originally called Dniprodzeržyns'k) , Dniprovska, and Kakhovka.

Pumped-Storage Hydroelectric Power Plant (PSHPP) is a hydroelectric power plant used to equalize the daily unevenness of the electrical load. In its work, *PSHPP* uses either a set of generators and pumps, or reverse hydroelectric units, which are capable of operating both in generator mode and in pump mode. During the nighttime decrease in electric power consumption, *PSHPP* receives cheap electricity from the power grid and uses it to pump water into the so-called upper beef (pumping mode). During the morning and evening increase in electricity consumption, the *PSHPP* discharges water from the upper reservoir to the lower reservoir and produces peak electricity, that is fed into the power grid (generator mode). There are three Pumped-Hydro Power Plants operating in Ukraine: Kyiv, Tashlyk, and Dnestrovsk.

Non-traditional (alternative) Power Plants are considered, first of all, solar, wind and biogas power plants. Solar power plants are power plants transforming solar radiation into electric energy.

Wind power plants transform kinetic wind energy in electrical energy. Biogas power plants are thermal power plants using organic fuel received from waste of plants, animals or agriculture or industrial production. These include alcohol mixtures, air, bio-oil, various gas combinations, etc. As of June 30, 2021, the total capacity of non-conventional power plants in Ukraine was 8044 MW [solar – 6351 MW (79,0%), wind – 1593 MW (19,8%), biogas – 100 MW (1,2%)] [7]). The largest number of non-conventional power plants are located in Zaporizhzhia, Kherson and Mykolaiv regions.

Electric energy is produced at the power plant in the form of three-phase alternating current. Direct current - required for industries such as electrochemistry, electrometallurgy, electrified transport, etc. - is obtained by converting three-phase current into direct current at conversion stations using rectifiers. The *Energy System* is a combination power plants, electric and thermal networks, connected together and connected by the common regime in continuous process of production, transformation and distribution of electric energy and heat at the joint management of this regime.

Rational distribution is possible in the energy system - the load between power plants, as a result of which fuel consumption is reduced due to the most complete use of nuclear power plants and reduction of the cost of electric energy.

Generators of electric stations produce, as a rule, electricity energy with a specified value of line voltage - 6.6 kV, 11 kV, 15 kV, 30 kV etc. - depending on the type of installed generator. This is to say because power plant generators are not connected to the power transmission line directly, but through transformer substations. The voltage of the line for the transmission of electrical energy must be selected in such a way that the energy transfer takes place with small losses for the lowest cost of transmission and the lowest consumption of cable products.

The active power transmitted along the three-phase current line is determined by the formula [8]:

$$\text{Ð} = \sqrt{3} \cdot U_1 \cdot {}^{2}{}_{1} \cdot \text{ñîs}\ \varphi, \ \text{[W]}. \qquad (5.1)$$

Power losses in electrical wires of a three-phase network can be determined by the Joule-Lenz Law:

$$Q = I^2 \cdot R \cdot t \text{, [J],} \qquad (5.2)$$

where Q is the amount of heat, [J]; I – current strength, [A]; R – conductor resistance, [Ω]; t is time, [c].

The value of electrical resistance depends on the material from which the conductor is made, the size of the conductor, the temperature of the conductor and is determined by the formula:

$$R = \rho \cdot \frac{\ell}{S} \qquad (5.3)$$

where (ρ) is the specific resistance of the conductor, (l) – conductor length, [m]; S – cross-sectional area of the conductor, [mm²].

Then the power losses in the electric wires of the three-phase circuit will be determined by the formula:

$$\mathit{\Delta}\text{Đ} = 3 \cdot {}^{2}{}^{2}_{1} \cdot \mathrm{r} = 3 \cdot {}^{2}{}^{2}_{1} \cdot \rho \cdot \frac{\ell}{S} \qquad (5.4)$$

From formulas (5.1) and (5.2) we get the formula:

$$\mathit{\Delta}\text{Đ} = 3 \cdot \frac{P^2}{3 \cdot U_1^2 \cdot \cos^2\varphi} \cdot \rho \cdot \frac{\ell}{S} = \frac{P^2}{U_1^2 \cdot \cos^2\varphi} \cdot \rho \cdot \frac{\ell}{S}, \qquad (5.5)$$

from which it follows that in order to transmit electrical energy over a distance with an increase in power, to reduce energy losses, it is necessary to increase the voltage.

In practice, the voltage is increased using a transformer substation, which increases the voltage to a value that depends on the amount of power being transmitted and the distance over which it is transmitted. There is certain relationship between voltage, transmission power and the length of transmission lines. For example, when transmitting power of 10÷50 MW over a distance of 50÷150 km, the line voltage increases to the value of 110 kV; 100÷150 MW and 200÷300 km – 220 kV; 150÷1000 MW and 300÷400 km – 300 kV; more than 1000 MW and more than 400 km – 500 kV, respectively.

Electric energy from the power plant to the area of consumption is transmitted via a high-voltage overhead or cable power transmission line.

An overhead power line is a facility for electricity transmission composed of wires located outdoors and fixed with the help of insulated structures and fittings or brackets and struts on engineering structures (bridges, overpasses, etc.). There are overhead power lines with voltage up to 1000 V and voltage above 1000 V (high voltage).

A cable power transmission line is a line for the transmission of electricity, or of its individual pulses, consisting of one or more parallel cables with connection, locking and end fittings and fixing parts, and for oil filled lines, in addition, with oil supply devices and pressure signaling system.

Depending on the type of current, power lines and cable lines are divided into *alternating current* and, accordingly, *direct current lines*.

After being transported by overhead line or high voltage cable to the necessary distance from the power plant to the consumption area, electricity is supplied to switchboards and substations.

Switchgear (SwG) is an electrical installation for the reception and distribution of electricity, containing switching devices, collective and connecting buses, auxiliary devices (compressors, batteries, etc.), as well as protection devices, automation and measurement devices. There are outdoor *SwG* s (the equipment is outdoor), indoor (the equipment is inside) and complete (the installation, consisting of cabinets and blocks with devices installed in them, devices for measurement, protection and automation and connecting elements, is intended for installation in premises).

A substation (ESS) is an electrical installation for the transformation and distribution of electricity, consisting of transformers or other converters of electricity, distribution devices, control devices and auxiliary facilities. There are substations of indoor transformers (*ESS*, whose equipment is located in a room or in a metal shell), attached (*ESS* closed, which has only one element in common with an adjacent room (a wall, partition or floor, which is an overlap of an adjacent room from below), built-in (closed substation, which has two or more construction elements shared with adjacent premises), complete (substation, consisting of transformers mounted in cabinets or installed outdoors, blocks of *SwG* s and other elements, supplied in an assembled form or fully prepared for assembly), pylons (*ESS*, all whose equipment is installed on the structures or on the support of the overhead contact line simply of the sky at a height that does not require protection from the ground).

The transformer substation, as a rule, reduces the line voltage to a value of 10 kV (district transformer substation).

Next, electrical energy over the air, or power transmission cable line, goes either to high-voltage consumers, or to the transformer substation, which reduces the line voltage to the value of 380 V (object transformer substation) to ordinary consumers.

An example of a simplified single-line circuit - all conductors that are necessary for the transmission of electrical energy are depicted by a single line - supply of electrical energy from the power plant to consumers of electrical energy is shown in fig. 5.3 (the figure shows the values of line voltages).

From the facility's transformer substation to the receivers of electrical energy, electrical energy is transmitted through the electrical network.

An electrical network is a set of electrical installations for the transmission and distribution of electrical energy, consisting of substations, distribution installations, power lines overhead and cable power transmission lines operating in a certain territory. The main difference between an electric line and an electric network is that an electric line is not branched, whereas the electrical network is a branched system of conductors.

Electricity networks are open (radial and main) and closed (ring, bilateral, double main, complex, etc.). In Fig. 5.4 the principle of the construction of open electricity networks is explained, and Fig. 5.5 - that of closed electricity networks.

Residential buildings with a height of up to five floors are usually powered by a main ring circuit with a disconnected jumper (as a rule, 4 buildings are powered). Three residential buildings are normally supplied with one cable line (nominal load), and the fourth house is supplied with another cable line (a third of the nominal load). In the event of an accident, the power supply is switched to another cable.

Residential buildings with a height of up to five floors are usually powered by a main ring circuit with a disconnected jumper - as a rule, 4 buildings are powered. Three residential buildings are normally supplied with one cable line (nominal load), and the fourth house is supplied with another cable line (a third of the

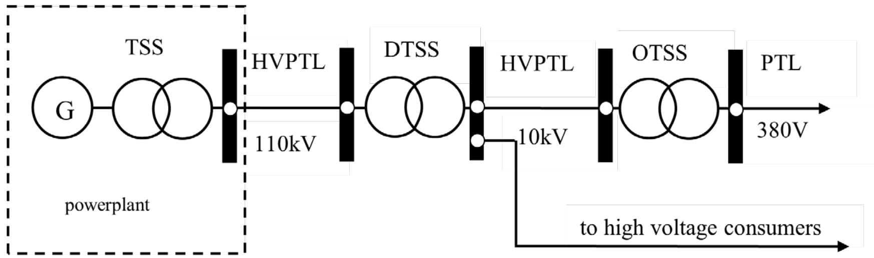

Fig. 5.3. An example of a simplified one-line scheme for the supply of electrical energy from a power plant to consumers of electrical energy G - generator of a power plant; TSS - transformer SS, which increases the voltage; HVPTL - high-voltage power transmission line; DTSS - district transformer substation that reduces the voltage; PTL - power transmission line; OTSS is an object transformer substation reducing the voltage

nominal load). In the event of an accident, the power supply is switched to another cable.

For residential buildings with a height of 5 to 16 floors, radial and trunk schemes (main circuits) with mutual redundancy of inputs are used. In this case, one of the lines is designed to supply power to the electrical receivers of residential apartments and working lighting of general construction facilities, and the second is for power lines to high voltage.

In residential buildings higher than 16 floors, electric receivers of emergency and evacuation lighting, fire extinguishers and elevators are supplied with electric energy from two independent mutually redundant power sources, and an interruption in their power supply - in the event of a disruption of the power supply

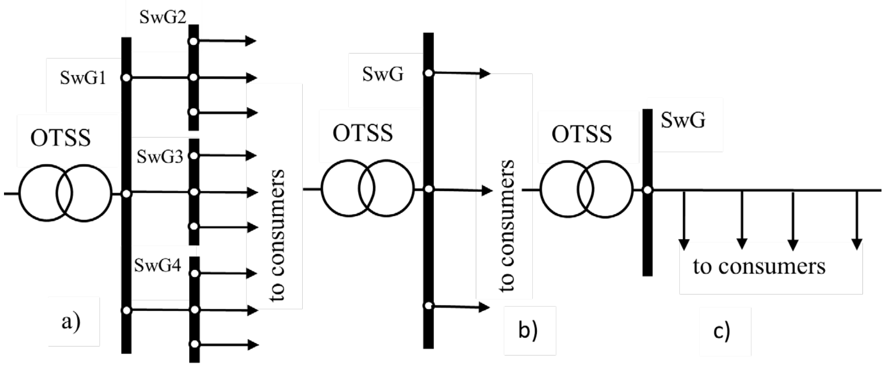

Fig. 5.4. The principle of construction of open electrical networks: a - distribution radial, b - concentrated radial, c - trunk OTSS - object transformer substation that reduces the voltage; SwG - switchgear is a distribution device

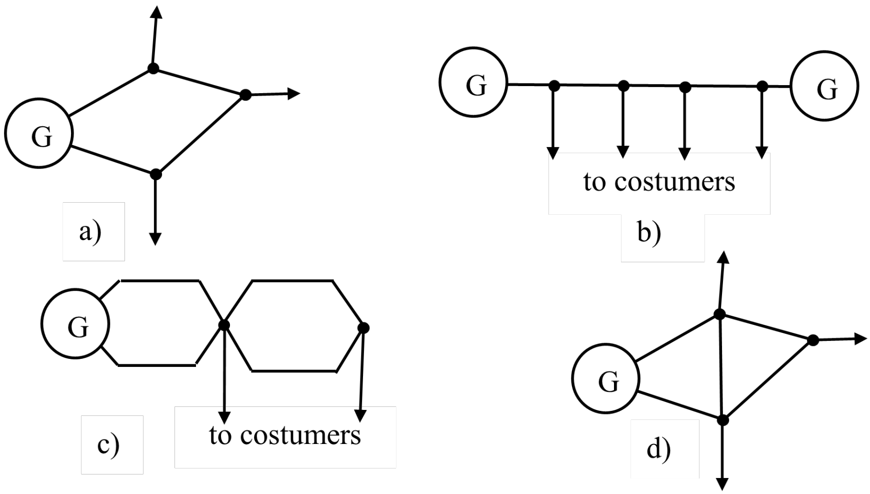

Fig. 5.5. The principle of construction of closed electrical networks: a – ring, b – bilateral, c – double trunk, d – complex closed

from one of the power sources - can be allowed only for the time of automatic power restoration.

A three-phase network with a linear voltage of 380 V is supplied to all residential buildings. For the purpose of electrical safety, only one phase with a voltage of 220 V is supplied to the apartments. A vertical distribution line departs from each input from which branches for powering individual apartments go through the floor distribution boards are located on each floor. Apartment panels with counters can be installed in apartments.

The main electricity receivers in residential buildings are lighting installations and electrical household appliances.

In public and administrative buildings, the same electricity supply scheme is used as in residential buildings. The lighting load prevails, but power electrical equipment can also be installed (electric motors for fans, pumps, refrigeration units, etc.).

As a rule, industrial enterprises are supplied with electricity from their own workshop substations. Receivers can be electric motors, electrothermal installations, electrochemical installations, lighting installations, etc.

In fig. 5.6 shows an example of a single-line diagram of a distribution radial electrical network from the object transformer substation to the receivers of elec-

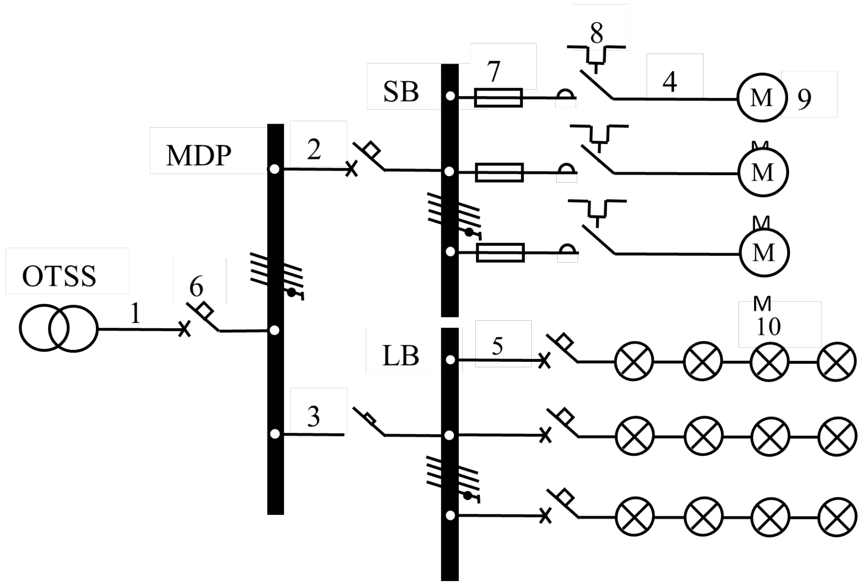

Fig. 5.6. An example of a single-line diagram of a distribution radial electrical network from the object transformer substation to the receivers of electrical energy

OTSS - object transformer substation reducing the voltage; MDP – the main Distribution Panel; SB – switchboard; LB is a lighting board; 1 – power supply network; 2 – power distribution network; 3 – distribution lighting network; 4 – branching to electric motors; 5 – group line of the lighting network; 6 – automatic switch; 7 – fuse; 8 – magnetic starter coil; 9 – electric motor; 10 – an electric lamp with an incandescent lamp

trical energy - electric motors and lamps.

Main Distribution Panel (MDP) is a panel through which electricity is supplied to the entire building or its separate part. The input and distribution device can perform the role of the *MDP* [9].

Input-Distribution Device (IDD) is an input device that also contains devices, and also devices on outgoing lines.

Input device (ID) is a set of structures, and devices installed at the input of the power line, into the house or in its separate part, powered by the *MDP*.

Accordingly, the types of electrical networks are introduced by:

- power supply network - a network from the distribution device of the PS or a branch from the overhead power lines to the input device, input-distribution device or MDP;

- distribution network - the network from the input device, input-distribution device or *MDP* to distribution devices and shields (SB, LB);

- group network - a network from switchboards and distribution devices (*MDP*, LB) to lamps, sockets and other electrical receivers.

Failure of any element of the power supply system leads to blackout. By analogy with the levels of emergency situations [10, 11], it is possible to introduce the concept of blackout by territorial coverage: state, regional, local and object level.

5.3 Standardisation of the reliability of electricity supply in Ukraine

Electric energy in Ukraine must be in accordance with the established quality standards. [12]. The standard [12] corresponds to International Standards IEC 868, IEC 1000-3-2, IEC 1000-3-3 – now obsolete. As for the quality standards of electricity, Europe is governed by the standard [13], adopted in Ukraine [14] since 2014 for confirmatory method.

According to [6], all consumers of electrical energy in Ukraine are divided into three categories of reliability, indicated by Roman numerals.

Electric receivers of category I - electric receivers, the interruption of electricity supply to which can cause danger to people's lives, significant damage to economic entities, damage to expensive basic equipment, mass shortage of products, disruption of a complex technological process, disruption of the functioning of particularly important elements of the municipal economy.

A special group of electrical receivers is distinguished from the composition of electrical receivers of the I category, the uninterrupted operation of which is necessary for an emergency shutdown of production, in order to prevent threats to human life, explosions, fires, and damage to expensive main equipment.

Electric receivers of category II - electric receivers, break the electricity supply of which leads to mass shortages of products, mass downtimes of workers, mechanisms and industrial transport, disruption of the normal activities of a significant number of urban and rural residents.

Electric receivers of category III - the rest of electric receivers that do not fall under the definition of categories I and II.

An independent power source of the receiver or group electrical receivers - a power source on which the voltage is maintained within the limits regulated by the Rules for Electrical Installations (REI) for the post-emergency mode when it disappears on another or other power sources of these electrical receivers.

Electric receivers of the first category must be supplied with electricity from two independent, mutually redundant power sources, and interruption of their power supply in case of disruption of power supply from one of the power sources can be allowed only for the time of automatic power restoration.

For the power supply of a special group of electrical receivers of the I category, additional power supply from a third independent mutually redundant power source should be provided.

As a third independent power source for a special group of power receivers and as a second independent power source for the rest of category I power receivers, local power plants, power system power plants, special uninterruptible power supply units, batteries, etc., can be used.

If power supply redundancy cannot ensure the necessary continuity of the technological process or if power supply redundancy is not economically feasible, technological redundancy must be implemented, for example, by establishing mutually redundant technological units, special devices for non-emergency stop of the technological process, which operate in the event of a power supply failure.

It is recommended to provide electrical receivers of II category of electricity from two independent mutually redundant power sources.

For power receivers of the II category, in the event of a disruption of the power supply from one of the power sources, interruptions in the power supply are permissible for a certain time, which is necessary to turn on the backup power supply by the actions of the staff on duty or the on-site operational team.

It is allowed to power electrical receivers of the II category one at a time airline, if it is possible to carry out emergency repairs of this line in a time not exceeding one day.

For power receivers of the III category, power supply can be performed from a single power source, provided that interruptions in power supply, necessary for the repair or replacement of a damaged element of the power supply system, do not exceed one day.

Power supply of all fire-fighting devices (fire pumps, fire-stop valves with an electric drive, centralized fire alarm system, fire alarm systems, fire extinguishing, electric valves on fire-fighting water pipes, detectors of explosive concentrations of combustible gases, explosive vapors, dust, etc.) is performed, as a rule, according to the first category of reliability.

For objects of various purposes, there are departmental documents that regulate, ensuring the reliability of their electricity supply. In particular:

- residential buildings [15, 16];
- public buildings and structures [16, 17];

- medical and preventive houses and structures [16, 18];
- buildings and buildings of educational institutions [16, 19];
- houses and buildings of children's preschool institutions [16, 20];
- houses of lending, insurance and commercial institutions destination [16, 17];
- cultural, entertainment and entertainment facilities [16, 21];
- sports and physical culture and health facilities [16, 22];
- department stores, shopping centres and stores [16, 23];
- parking lots and garages for cars [16, 24];
- telephone exchanges [25-27];
- boiler rooms [28];
- subway buildings [29];
- nuclear power stations [30];
- external networks and gas supply facilities [31];
- poultry enterprises [32];
- livestock enterprises [33-37];
- buildings and structures for storage and processing of agricultural products [38-39];
- warehouses of oil and oil products [40].

The strictest requirements regarding the reliability of power supply are advanced to electric receivers of the special group I category. Therefore, such receivers are relatively rare. Of the objects listed above, the electricity receivers of the special group I category are:

- electric receivers of operating and maternity units, departments of anesthesiology, intensive care and intensive care, laparoscopy, bronchoscopy and angiography rooms and other rooms, on the smooth operation of which the life of sick medical and preventive buildings and structures directly depends [regardless of the presence of mutually redundant transformers, it is necessary to provide a diesel electric station (DES), an uninterruptible power supply unit (UPS) or accumulator batteries);
- electrical receivers of fire protection systems, elevators, emergency lighting, security alarm, gas alarm of banks and bank vaults of buildings of lending, insurance and commercial institutions;
- electrical receivers of telephone exchanges with a capacity of 3,000 or more numbers;
- traction, traction lowering and lowering substations of lines metro and electric depot, energy control points, telecontrol and remote sensing devices of the

power supply system, automation and telecontrol of train traffic (ATTT), automated fare payment system (AFPS), contact persons, devices of the station work management system metro with the use of telemonitoring (SCST), emergency (evacuation) lighting, lighting of evacuation routes for passengers and personnel from the underground buildings, dispatch centres, server buildings of the subway;

- equipment of the information and control system of the automatic fire station signaling of Nuclear Power Plants (NPP) (two independent power sources and batteries with the calculation of operation for 24 hours in standby mode and 3 hours in "fire" mode).

Less strict requirements regarding the reliability of power supply are being put forward to electric receivers of the I category. Of the objects listed above, electric receivers of the I category are:

- electric receivers of fire protection systems, gas alarm, elevators, emergency lighting (safety and evacuation lighting), light fence lights in residential buildings and dormitories, public buildings and structures higher than 16 floors (47 m) to 25 floors (73.5 m);
- electric receivers of fire protection systems, gas detection, elevators, emergency lighting, security alarm of buildings of institutions, organisations, offices with more than 2,000 employees, regardless of the number of floors of public buildings and structures;
- electrical receivers of fire protection systems, gas alarm, hospital elevators, emergency lighting, security alarm of medical and preventive buildings and structures;
- electric receivers of fire protection systems, gas alarm, emergency lighting, security alarm of buildings of educational institutions in which more than 1000 people study, buildings and structures of educational institutions;
- technical means of the automated system for managing the banking activity of buildings of lending, insurance and commercial institutions;
- electrical receivers of fire protection systems, gas alarm, emergency lighting, security alarm; the rest of the electric receivers with a total number of seats in halls of more than 800 and children's entertainment facilities regardless of the number of seats of cultural and entertainment and recreational facilities;
- electrical receivers of fire protection systems, gas alarm, emergency lighting, security alarm of indoor sports facilities;
- electrical receivers of fire protection systems, gas alarm, emergency lighting, security alarm of department stores, shopping centres and shops with sales halls with a total area of more than 2000 m^2;
- electrical receivers of fire protection and air environment control systems,

emergency lighting, security signaling of parking lots and garages for passenger cars;

- electrical receivers of telephone exchanges with a capacity of less than 3,000 numbers;

- boiler rooms of the first category (a boiler room that is the only source of thermal energy of the heat supply system and provides consumers who do not have individual backup sources of thermal energy);

- electric receivers of fire protection systems, installations of fire extinguishing and fire alarm and smoke protection, electric receivers of air support in stairwells, elevator shafts, electric dampers for smoke removal and electric motors against smoke protection, fire retardant valves with an electric drive, hermetic valves of civil protection installed in vestibule-gates, traction (contact) network 825 V, escalators, elevators and their control systems, networks of fire warning and evacuation management systems, artesian and fire pumps, ventilation shut-off equipment, duplicating sound signal of automatic fire alarm and fire extinguishing systems, water valves with electric drives, pumping water discharge systems, working station lighting and tunnels, passenger automation devices, fans for tunnel ventilation of subway facilities;

- automatic fire alarm installations for NPP premises containing systems of normal operation, important for safety, as well as for special housing, fresh fuel storage, spent fuel and radioactive waste storage, radioactive waste incineration housing, organic fuel management, cable structures, turbine compartment and installations, transformers of nuclear power stations;

- poultry farms producing eggs with a capacity of 100,000 or more hens; Poultry farms in the meat sector with the cultivation of 1 million or more broilers per year; farms for breeding flocks of chickens for 25 thousand and more heads, as well as geese, ducks and turkeys for 10 thousand and more heads;

- milk production complexes and farms with 400 or more cows; complexes for growing and fattening cattle of at least 5,000 heads; complexes for growing and fattening pigs with at least 12,000 heads;

- electrical receivers of oil pumping warehouses and petroleum products (SNN) intended for export operations, as well as stationary fire extinguishing installations (fire-fighting pumps, fittings for the supply of fire-extinguishing substances, etc.) and electric receivers of receiving stations of fire and security alarms, regardless of the category of SNN in terms of capacity.

Very often, as for the reliability of the power supply, power receivers are assigned to category II. Of the objects listed above, category II power receivers are:

- electrical receivers that do not belong to the special group I category and

I category of residential, public, medical and preventive buildings, educational institutions, buildings of lending, insurance and commercial institutions, department stores, shopping centres and shops with sales halls with a total area of more than 2000 m^2, parking lots and garages for passenger cars, subway facilities, Nuclear Power Plants;

- residential buildings with a height of up to 16 floors, including electric stoves and electric water heaters for hot water supply, with the exception of one- and eight-apartment buildings; residential buildings more than 5 stories high with stoves on natural, liquefied gas or solid fuel;
- buildings of institutions, organisations, offices with a height of up to 16 floors inclusive, with the number of employees from 50 to 2000 inclusive;
- buildings of educational institutions in which more than 200 to 1000 people study inclusively;
- electrical receivers of buildings and structures of children's preschool institutions;
- electrical receivers of stage lighting, stage mechanisms, technical hardware and sound systems with a total number of seats in the halls of more than 800; the rest of the electric receivers with a total number of seats in the halls of more than 300 to 800, including cultural, entertainment and recreational facilities;
- trade enterprises with a trading area of more than 250 m^2 up to 2000 m2 inclusive;
- boiler rooms of the second category (boiler rooms that do not belong to the first category);
- poultry farms with a lower production capacity than previously indicated for consumers of the I category (electricity interruption - no more than 3.5 hours);
- livestock farms with livestock less than specified for the 1st category (power supply interruption - no more than 3.5 hours);
- electrical receivers of buildings and structures for storage and processing of agricultural products - electric receivers of food pumping warehouses of I and II categories of SNN.

It can be concluded that a properly designed and functional power supply system for objects of various purposes should ensure the required reliability of power supply for objects of various purposes and, as a result, protect the population, the territory, the natural environment and property, in the event of emergency situations leading to the disconnection of electrical receivers from the main sources of electricity supply.

5.4 Features of ensuring the reliability of electricity supply during Martial Law in Ukraine

On February 24, 2022, the open military attack of the Russian Federation on Ukraine began. Missile strikes on the territory of Ukraine, especially after the September counteroffensive of the Armed Forces of Ukraine, led to a massive blackout.

Practically, objects of the special group I category of power supply reliability remained operational during a blackout (provided there is no direct impression and the serviceability of a third independent power source in the form of its own special uninterruptible power supply units, batteries, etc.). The above analysis shows a rather narrow list of objects of the 1st category of electricity supply reliability, which in general makes the normal life activity of a significant number of urban and rural communities impossible. Objects of the remaining categories, as a rule, remained without electricity supply, which led to a significant disruption of the normal life activity of a significant number of urban and rural communities.

Table 5.2 analyzes the possible negative manifestations of a blackout, their danger and ways to reduce it.

Table 5.2. Analysis of possible negative consequences of a blackout and ways to reduce them

Negative manifestation of blackout	The greatest danger	Ways to reduce the danger
Lack of electricity supply to residential buildings with electric stoves	Inability to cook hot food	Availability of alternative appliances for cooking (kerosene stove, traditional (tourist) stove ("fisherman's stove"), chemical heating sources, etc.
Lack of electricity supply to residential buildings	Malfunction of the water supply system	Availability of the necessary supply of drinking and technical water; arrangement of wells, water towers, use of water from available natural sources
	Inability to charge mobile phones	Each user has a Power Bank, a battery source of uninterrupted power supply, a portable electric generator, etc.

Lack of electricity supply to high-rise buildings	Failure of the elevator system, which leads to the impossibility of climbing to the upper floors, or blocking passengers inside the elevator	The use of stairwells during the announcement of an air alarm even when the elevator is operating
Lack of electricity supply to buildings with electric-dependent gas heating	Impossibility of operation of the heating system, failure of the heating system (defrosting)	Application of low-power backup sources of electricity power supply (battery source of uninterruptible power supply – provides operation during the time limited by the consumption power and battery capacity; portable electric generator – provides operation during the time limited by the liquid fuel supply; etc.)
Lack of power supply to the notification systems	Impossibility of informing the population about any dangers	Installation of backup power sources
Lack of electricity supply to medical and preventive buildings and facilities	Danger to human life during the operating room activities, the impossibility of providing medical services to the population	Electrical equipment for operational activities is assigned to a special group of reliability category I. For the rest of the consumers - installation of their own backup power sources
Lack of electricity supply to buildings and structures of educational institutions	Termination of the educational process	Evacuation, organisation of distance learning
Lack of electricity supply to children's preschool institutions	Termination of the educational process	Evacuation, temporary closure or installation of backup sources of electrical power
Lack of electricity supply to cultural spectacles and leisure facilities, sports and physical culture and health facilities	The danger caused, in particular, by the termination of the electrical lighting	Evacuation, temporary closure or installation of backup sources of electrical power

Lack of electricity supply to department stores, shopping centres and shops	Cessation of electric lighting, inoperability of cash register equipment, etc.	Evacuation, installation of own backup power sources
Lack of electricity supply to banking institutions	Impossibility of using electronic banking services; failure of the security system	Shutting down or installing backup power sources
Lack of power supply to fixed telephone exchanges	Lack of connection, inoperability of the Internet, impossibility of using electronic banking services	At telephone exchanges with a capacity of 3,000 or more numbers, it is provided for the installation of a backup source of electrical power, as a rule, an automated diesel electrical station designed for a long period of operation. Installation of backup power sources at telephone exchanges regardless of capacity
Lack of power supply to cellular base stations	Lack of cellular connection, inoperability of the Internet, impossibility of using electronic bank payments	The presence of a battery back-up source of uninterrupted power supply, a portable electric generator, etc. with automatic input of the reserve
Lack of power supply to the boiler rooms	Shutting down the heating system	Setting up your own independent power source
Lack of electricity supply to metro facilities	Suspension of transport, blocking of passengers in tunnels, on escalators, failure of the ventilation system	Most of the life support systems are assigned to the special group I category
Lack of electricity supply to poultry enterprises	The death of birds in the event of an interruption of the power supply for more than 3.5 hours	Poultry farms of large capacity are classified as I category with a power supply interruption of no more than 3.5 hours. In the case of longer interruptions, the arrangement of an independent power source
Lack of electricity supply to livestock enterprises	Death of animals due to prolonged absence	Setting up your own independent power source

Lack of electric street lighting at night	Injury to pedestrians as a result of their own carelessness Pedestrian injuries as a result of traffic accidents	The presence of each person's own flashlight, in particular in a mobile phone, to illuminate the paths of traffic The use of reflective clothing elements, giving light signals to drivers using their own flashlight
Termination of electric traffic lights	Traffic accidents as a result	Personal discipline of vehicle drivers, clear
Regulation of street traffic	Unpreparedness of drivers to regulate traffic with the help of road signs and road markings	Compliance with traffic rules

It is possible to conclude that objects of special group I category, as a rule, remain able to work at emergency shutdown of electric power supply (blackout) because of presence of own (object) reserve power (supply battery backup source with uninterrupted power supply, portable electric generator, etc. with automatic backup). The rest of the facilities cannot remain operational due to damage to the main and backup (not belonging to the facility) sources of electrical power. Ensuring the operational efficiency of the object is determined by the desire and capabilities of the owner of the business entity to arrange its power supply system according to the scheme of the special group I category of power supply reliability. It is not forbidden to increase the category of reliability of the object's electricity supply above the requirement at the legislative level – in this case, economic expediency and desire to continue further work comes to the fore.

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