# Adverse Event in a Medical Facility - Blackout

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*Abstract:* -The article deals with an adverse event - blackout. Its history in the world and the Czech Republic, causes, consequences, and measures are addressed here. Nowadays, when most important sectors, companies, and households are completely dependent on the electricity grid, prevention, preparedness, and measures cannot be neglected. A hospital facility was chosen to illustrate the necessary measures, as healthcare is one of the most important sectors. Care for human health and life will always be at the forefront of protected interests. It describes the division of priorities within the hospital in terms of electricity supply in the normal state and the event of an adverse event, ie a blackout. Finally, the different types of backup resources used to back up these objects and systems are described.

*Key-Words:* - blackout, electricity, generator, hospital, measure, prevention, security, threat.

## 1 Introduction

The whole world is increasingly dependent on electricity. We need it at work, at home, at leisure. All sectors of industry, trade and other components necessary for the functioning of the economy depend on a continuous supply of electricity. However, great care should be taken in healthcare, whose dependence on electricity is operating in operating theaters, intensive care units, and directly existential aftercare.

The power system and its entire system are very susceptible to disruption, whether natural or human. Its management and especially the prevention of these adverse events are very important for proper and uninterrupted functioning. This system consists of individual elements that are interconnected and operate in direct dependence on each other. The main reason this system has to be continuously protected is the fact that electricity is not a storable source. Therefore, the balance between production and consumption must be permanently maintained. An emergency of the Blackout type may cause a disruption of several or all elements of the power system. Such disruption necessarily leads to crisis situations and accidents. These affect important critical infrastructure actors on which the function of the territorial unit itself depends on the worst-case scenario. Large-scale accidents may exceed the capabilities of certain hospitals, businesses, municipalities, and states. The ability to immediately resume operation is very important, its absence could lead to secondary crisis situations. Particularly in medical facilities, even a brief stoppage of delivery can lead to health-threatening moments, ultimately to the death of patients. Power outages, even smaller than Blackout, are currently a real threat to the entire functioning of society and preventive measures must be taken before these threats occur. It is very important that critical infrastructure objects that are necessary for the proper functioning of the territorial unit are prepared for the failure situation. It must deal in advance with the issue of power outages, its consequences and the subsequent possibility of using alternative power sources for their solution.

The article consists of an overview of what energy security is, what we call blackout, its causes, and consequences. It offers its occurrence - worldwide and in the Czech Republic, critical infrastructure preparedness of the Czech Republic, its legislation on this problem and, in the end, backup sources - diesel aggregates and their types.

Energy security means: "Ensuring the continuity of the necessary energy supplies and energy services to safeguard the protected interests of the State". Energy security corresponds to three energy subsystems:

- Security of energy supply and transport,
- Energy transformations
- Energy security of final energy users.

# 2 Blackout

This is a complete outage of large-scale power supplies for tens of hours to days. This failure will ultimately affect a large number of people and may affect several countries. The power supply to the users and the potential-free state is interrupted in all or part of the electrical network.

Often the breakdown of the electricity system and the emergence of island operations. For operations with sufficient control capacity and a balanced production and consumption balance, the operation can be maintained until it is reconnected to the electricity grid.

## 2.1 Causes of Blackout

The widespread power outage caused by the collapse of the power system is usually caused by several causes at once. these, created separately, would otherwise do not cause any major complications. The power system is designed and constructed in such a way that the rejection of one element does not result in the rejection of the follower. The only exception is the combination and sequence of individual partial failures. In most cases, natural factors are to blame.

There are three possible causes of blackout in the Czech Republic that could occur:

- a technical cause linked to disruption of electricity production and consumption. This is mainly related to overflows from abroad, specifically from Germany. the electrical system works flawlessly only if the balance between generation and consumption of electricity and the timely resale or disposal of its surplus is continuously managed,
- extreme weather manifestations, which have been occurring more frequently in the Czech Republic recently, mainly due to global warming,
- a controlled terrorist attack capable of disrupting the state's CI for several months, with fatal consequences in the form of society's disintegration, economy and, over time, the whole state.

However, there are many more causes of power outages:

- natural disruption - grid failure (windstorm, prolonged snowfall or heavy icing, solar storm),
- interconnection of transmission systems of technology or a heavy load of a transmission system,
- human factor errors - operation,
- age of power lines and all its important components,
- as well as cyber-attack and terrorist attack.

## 2.2 Kinds of Blackout

Blackout can be divided into many groups, for clarity we now divide it into four groups in terms of place and time:

a) Short-term blackout - after the blackout, the electricity supply will resume within a maximum of tens of minutes to a few hours.
b) Long-term blackout - blackout will last in tens of hours to days, so it is a blackout with all possible more or less serious consequences for the population.
c) Local blackout - the electricity grid is disrupted in a smaller area, such as the municipality.
d) Extensive blackout - will affect the larger territory of the region, the whole Czech Republic and surrounding states with very serious consequences, not only primary but also secondary, as will be explained below.

According to crisis management in the Czech Republic, a blackout can be categorized into three levels, which are divided according to time severity.

a) "First-level Blackout" - this is a breakdown of the transmission system operation, where there is no damage, or only a minor one, a blackout of this type is usually repaired quickly and PS recovery should be a matter of hours.

b) “Second stage blackout” This stage of the blackout already damages one or more parts of the transmission system. It is most often caused by radical manifestations of the weather when the storm or hurricane can fall branches or. whole trees on wires wiring. Another example of an extreme meteorological phenomenon is icing, which can also cause significant complications, such as causing the transmission system masts to tear. The time from damage to the line, through repair to the restoration of electricity supply can take days to weeks.

c) "Third-level blackout" these third-level blackout occurs most often by a deliberate attack on coupling transformers that connect the transmission system with the distribution systems. They also contain a lot of coolant transformer oil, which is why fires often occur when damaged. Their repair and replacement take several months. Operators have limited reserves and it takes a long time to build another transformer.

### 2.3 The course of Blackout

The emergence of an unbalanced state, for example, due to a failure of a part of the transmission system, can cause a so-called domino effect, on one hand automatically reducing electricity consumption due to overloading the system and on the other hand. The resulting damage to power generation, transmission and distribution facilities is many times smaller than the secondary consequences of power outages. The reason is the already mentioned domino effects, which arise from the interconnection of the whole critical infrastructure. The resulting damage to power generation, transmission and distribution facilities is many times smaller than the secondary consequences of power outages. The reason is the already mentioned domino effects, which arise from the interconnection of the entire critical infrastructure. Availability of information when needed and coordination of actions between neighboring operators systems lead to quick implementation of necessary repairs and other measures. these will then contribute to the rapid commissioning of the system.

Completely eliminating the risk of blackout is not technically and economically feasible. therefore, at least general rules and solutions exist and must be followed to minimize the potential impact that the fault triggers.

Blackout will not work:

- Rail Transport: electrified tracks do not run in the event of a power failure,no alarms on track.
- Traffic: traffic lights do not work, traffic jams and more accidents, complications when refueling. Public transport is very paralyzed.
- Industry: it is electrified, mainly controlled by computer systems and would, therefore, be inoperative. Infrastructure: Not all computer systems would work, ie. landline, mobile telephones, banking services, card payments, cash registers, cameras, radars, photocells, etc.
- Supplying food and goods: Families have supplies for a few days, but some would depreciate broken refrigerator. Waterworks: Its operation is limited to the gravity range and supplies.

It should be noted, however, that each of these units has its own characteristic time course and they are all strongly interrelated. For these reasons, it is difficult in a particular case to predict the real impact on human and social life. [1]

## 3 Blackout in history of the world and Czech Republic

In a detailed survey of the history of blackouts, it is apparent that the large ones that hit a large population were most often found in America. However, it is necessary to take into account the exact causes of blackouts that do not objectively occur in Europe. In fact, blackouts in America are mostly caused by natural elements such as tornadoes. The most important blackouts in the world have affected tens to hundreds of millions of people and have caused not only panic and despair of those affected, huge damage to property, but above all damage to human lives. Of the last blackouts were the biggest:

USA

The Northeastern United States and part of Canada were hit by a blackout on August 14, 2003. It affected 50 million people, including New York, Cleveland, and Detroit. The energy company partially resumed its services in just two hours, but in some places, the outage was longer than 24 hours. Trains, elevators, in particular, were out of operation, and operations at airports and hospitals were interrupted. The New York Stock Exchange continued to trade thanks to backup sources. Oio First Energy Corporation was found to have neglected network maintenance, with surrounding trees falling off power lines and causing a chain reaction of outages. [2]

India

There were two massive power outages here, in 2012. They affected over 670 million people when the northern, eastern and north-eastern distribution networks failed at the same time. This in turn caused

the world's largest power outage. The failure affected 19 Indian states out of a total of 28, whose total population exceeds the population of the European Union. The first outage was the reason for the failure of two other distribution networks, which unfortunately later led to their subsequent collapse. India's grids are still not ready for a fast-growing economy.

Holland
The blackout was caused by a high voltage station in Amsterdam. On March 27, 2015, a transformer station failure occurred, where before ten in the morning a power outage complicated operations at the fourth largest airport in Europe, Amsterdam Schiphol. The outage first affected North Holland and Flevoland, followed by other areas.

Turkey
A massive power outage in 2015 affected more than half of the country. The cause of the blackout was errors at the electricity distributor. Two power plants in Izmir and Adana were disconnected, but at that time maintenance was underway on other transmission routes. This load the Turkish network failed to cope with the collapse of the first high voltage line and was followed by another five routes that did not withstand congestion. This blackout affected 70 million people for several hours. Italy, as well as Albania, Macedonia and Kosovo, experienced a major power outage, where the entire electricity supply system collapsed, just in times of great heat and fire. [3]

Russia
On November 22, 2015, the Crimean peninsula found itself without electricity. The cause was a terrorist attack that destroyed power pylons leading from the Ukrainian interior. Two million people were without light, water and heat. Shopping centers were closed, there was no public transport and the telephone connection did not work. Crimea has connected its internal sources of electricity supply. These are solar and wind power plants, which together with gas and mobile diesel power plants are capable of basic electricity consumption. The energy supply was not completely restored even after a month.

These large-scale blackouts have affected tens to hundreds of millions of people several times in history and have always caused not only the confusion and despair of those affected, but also damage to property and, unfortunately, to human lives.

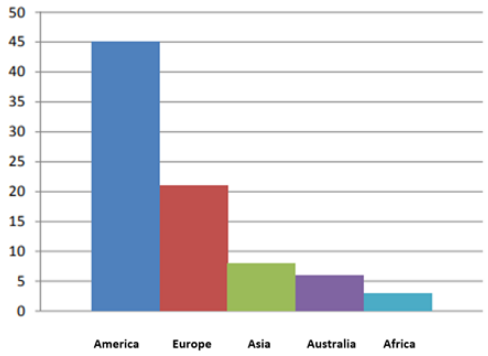

Figure 1. Blackout in the world

In the past of the Czech Republic, the following conditions occurred, when it was not far from the total blackout:

a) The state of emergency in 2006 (it was not a typical blackout), the regulation level for large customers was announced, and households were not affected. in the summer season, there was a huge onslaught on electricity due to high temperatures and the subsequent operation of air conditioning units. There were a momentary restriction and redistribution of electricity flow between companies, households were not affected.
b) Hurricane Kyrill 2007 and Emma 2008 (Kyrill destroyed mainly forests, hurricane Emma caused damage to the electricity system) was affected by about 1 million current.

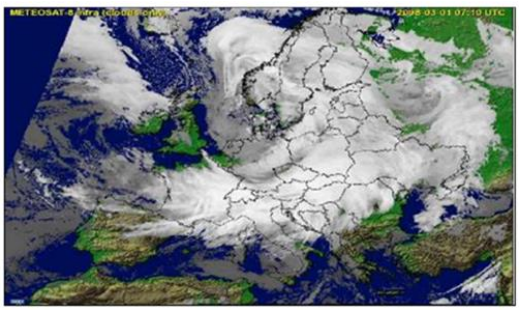
Figure 2. Hurricane Emma on March 1, 2008

c) Storm Fabianne 2018 - (power outages due to fallen trees) the result was in the form of 160 thousand. households without electricity.

## 4 Blackout in Czech Republic

In some situations, the Czech transmission system has to handle transmission up to three and a half times higher power flow than it is usually used to.

This is mainly due to the performance of the German wind parks, and the significant increase in the performance of the German photovoltaic power plants also contributes to the critical situation. [4]

*Legislation of the Czech Republic*

In the Czech Republic, from an energy point of view, they apply the following laws: above all, Act No. 458/2000 Coll., On business conditions and state administration in the energy sectors and amending certain acts (the Energy Act), which was approved on 28 November 2000 and came into effect on 1 January 2001, is essential. This Act is enshrined in particular terms such as reliability and quality of supply. It also defines the state of emergency, which is declared and terminated by the transmission system operator for the whole country. This is followed by the State Energy Concept of the Czech Republic, a document that determines the strategic goals of the state in the energy sector. [5] further in the case of a declaration of a state of emergency, the government, the Ministry of the Interior and, in the event of a concern, the neighboring regions are informed. [6]

The main idea and mission of the SEC is the maximum independence of the Czech Republic in securing energy supplies. ensuring a reliable and uninterrupted supply of energy for the requirements of the population and for the functioning of the national economy. All this at affordable and competitive prices. It is also a privilege to ensure uninterrupted energy supply in crisis situations. Individual towns of the Czech Republic should also prepare territorial energy concepts according to Act No. 406/2000 Coll., Of 25 October 2000. The Territorial Energy Concept should assess the state of the area, the visions for the future, the increase in consumption foreseen, and where the whole energy sector of the city will go, as well as manuals for municipal councils and their officials on how to proceed in an emergency and how to minimize the consequences of an emergency. General procedures can be used to assess the threat. Risk assessment procedures are site-specific, as local vulnerability plays a key role here. [7]

*Preparedness of critical infrastructure of the Czech Republic*

Critical infrastructure is a set of physical, cybernetic and organizational systems that are necessary to ensure the protection of lives and health of people and property, minimal running of the economy and state administration. Electricity supply is crucial for all other sectors of human activity. If the supply of electricity is limited, then there is a risk of not only economic efficiency, but also to endangering property and especially human health and lives.

Priorities of power supply after blackout (issued by the Energy Regulatory Office of the Czech Republic, 2012):

- nuclear power plant's consumption,
- own consumption of system classic power plants,
- the capital city of Prague,
- large conurbations,
- other consumers.

The current legislation of the Czech Republic does not yet contain provisions on the solution of the operational situation and emergency supply “beyond the state of emergency”. At present, the distribution system is not able to function without interconnection with the transmission system and the distribution system operator is not liable for damages caused by a power failure in the event of a transmission system failure. In the Czech Republic, there is a state-owned company CEPS (a company providing electricity transmission system operator in the Czech Republic), which takes care of the stability of the electricity network and cooperates on exercises simulating blackouts. It is integrated into European structures. [8] It can also be used last part of the crisis preparedness plan is the so-called auxiliary part. This section provides an overview of the legislation used for the preparation and management of negative phenomena of the crisis. This section also includes an overview of the 38 contracts concluded to ensure the implementation of this plan, both with the crisis preparedness plan treat, geographical background, and other various related documents with negative events. [9]

A unique solution for both shortages and surpluses of electricity is a hydroelectric power plant with the largest installed capacity in the Czech Republic - Dolni Strane. The pumped storage power plant pumps water from a mile and a half through a long pipe from the bottom up (and consumes energy), and then drains it down again and produces electricity. So the water is drawn up when there is enough electricity. On the contrary, it is lowered from above through the turbine when there is a shortage of energy at peak times and it is necessary to produce it quickly. In this way, Dlouhe Strane makes it possible to keep the Czech electricity

network stable. It takes seven hours to pump the upper tank, and then the power plant can supply full capacity to the grid for six hours. It will thus return electricity to the grid as needed with an efficiency of about 75%. The turbines work in both directions here. The water spins them downwards and the generator connected to them produces electricity. This generator also functions as an electric motor, which spins the turbines upside down and brings the water back into the upper tank. These are two Francis turbines, each with an output of 325 MW, which uses a gradient of over 500 meters and a flow rate of up to 75 cubic meters per second. The upper reservoir is located on top of the Dlouhe Strane mountain at an altitude of 1,350 meters, covers an area of 15.4 hectares, and has a volume of 2.7 million cubic meters. The lower reservoir on the Divoka Desna river at 825 meters above sea level has an area of 16.3 hectares and a volume of 3.4 million cubic meters. [10]


Figure 3 Dlouhé stráně - pumped storage power plant [10]

## 5 Backup power generators

Short-term outages cannot be avoided, so important and heavily dependent institutions (such as hospitals) are usually protected by uninterruptible power supplies, including backup power generators. In less important cases, at least uninterruptible power supplies (containing accumulators) are used to bridge a short-term power failure or provide enough power to shut down or go into emergency mode. Equipment belonging to critical infrastructure must, therefore, have safety power supplies installed to provide power for a specified period in the event of a failure of the primary power supply. Stationary diesel engines are permanently located in individual objects cannot be manipulated as needed. [11]


Figure 4. Diesel generator in container design with additional fuel tank

Uninterruptible power supplies naturally have a limited number of hours of operation, since they only start when there is a disruption of public utility supply. But the more hours the backup power source works, the more important the fuel choice becomes. Uninterruptible power supplies according to fuel type: Diesel and Gas - the Czech operating regulation requires so-called “fuel on the spot” - therefore it cannot be used. Diesel aggregates will always have a unique position in the back-up market, best meeting demanding requirements.

However, for their trouble-free use, care must be taken to ensure that fuel tanks that require refueling, maintenance, regular refueling, regular serviceability testing, service as required by manufacturing technology. Among the key features of the diesel generator are its reliable start, very fast achievement of the correct operating speed and the ability to deliver full power to the load. This is due to several factors: the operability of the starter, the condition of the starter battery (voltage, capacity, but also the status of contacts and cables), the condition of the oil charge (temperature, oil, and filter quality), the condition of the fuel injection system and fuel quality.

Among the strengths of the functionality of the diesel generator are almost "Endless" operation with a continuous supply of fuel. Then unlimited backup of critical points dependent on the uninterrupted supply of electricity. The possibility of increasing the output of diesel generators is important. The individual diesel generators are able to cooperate and supply the necessary voltage. The disadvantage of operating diesel generators is the need unmodified fuels. otherwise, the motors become heavily clogged and the equipment fails frequently.

## 6 Blackout and medical devices

Global demand for electricity is still growing, as are demands on transmission systems. The risk of their overload, failure or local blackouts has an increasing tendency, which will continue to increase and at the same time will be less predictable than before. The readiness of medical facilities must therefore be ensured so that no unpredictable situation arises to which it will not be possible to respond adequately.

Blackout in New Zealand – 1998 The outage occurred in 1998 in February and March in Auckland, lasting five weeks and paralyzed the operation of hospitals, factories, and staff found themselves out of work. The defect was caused by high voltage power lines. From this The incident still involved various power outages for eleven years of energy. [12]

Compared to other countries in Europe, the Czech Republic is relatively well secured against a blackout, but the risk of a possible outage can never be ruled out. ČEPS ensures safe and reliable operation of the electricity system, however, with increasing demands on energy consumption, the risks also increase. There can be several reasons that cause network instability leading to a subsequent blackout, and it was mentioned above in the article. It is therefore very likely that a large blackout may occur in the Czech Republic when several factors coincide. In such a case, a state of emergency will be declared and the regulation levels of electricity consumption will be declared. It is therefore necessary to reduce these risks to an acceptable level. The measures have a significant effect on risk mitigation, but they are a burden on the hospital economy. The replacement of equipment, which is minimally active, is ensured by legislative standards rather than the depreciation itself and the technical inadequacy of the devices.

The issue of blackout in hospitals affects many areas, each hospital has an elaborated energy concept, but the levels of preparedness in them are not uniform. The backup power supply is used to ensure an uninterrupted supply of electricity. Backup sources are used in data centers, production lines, power plants, telecommunications systems, medical facilities. If there is a power failure, the backup power sources will start. In the Czech Republic, the establishment of a back-up aggregate by a health facility, newly built, is imposed by the standard ČSN 33 2140 on electrical wiring (for medical purposes). They are further obliged to divide their premises according to the following priorities: Lighting and power supply of operating theaters, Safety lighting and equipment, Other electrical equipment, eg selected fire lifts, Lighting escape routes, emergency rooms.

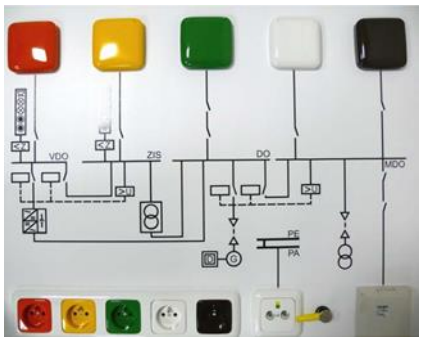


Figure 5 Marking of socket outlets (according to ČSN 33 2140), it is an ABB training panel dedicated to the FBMI CTU for educational purposes

Green color of socket cover (RAL 6018) for connection of medical and other electrical appliances devices which must have emergency power supply but interrupt within 2 minutes (which is the longest the time when the voltage at these outlets is restored) will not endanger the life or health of patients, it will not endanger the basic operation of the medical facility and will not cause irreparable damage. In case of trouble-free operation, these sockets are powered from the basic power supply a malfunction at the base source or a malfunction at the power supply are supplied from the main emergency resources. The emergency source is usually a diesel generator with automatic start. This resource supplies power for the entire time the power supply is interrupted from the base power supply. The letter designation will use the letter D because of the circuits they have Ensure power supply from the main emergency power supply are called important circuits.

Yellow color of drawer lid (RAL 1018) for medical insulated system that is used for the supply of medical electrical equipment, the nature of which excludes eliminate the first insulation fault by interrupting the power supply and thus shutting down the device because of discarding operating equipment could endanger the life or health of patients. Transformer used for creating a medical isolated system has a primary winding powered from critical circuits. The failure of the medical isolated system is signaled by optical and decommissionable acoustic signaling. The letter designation will use the letter Z as an abbreviation for medical isolated system.

The orange color of the socket cover (RAL 2004) is designed for outlets of very important circuits, which is in principle a medical isolated system with an even higher degree of security of supply electric power because the primary winding of its protective isolation transformer is powered by UPS, practically always operating in on-line mode, without power interruption connected devices (max. 15 seconds according to ČSN 33 2140).

Because it has an emergency source limited power and limited operating time, can only be powered from this type of outlet they do not have medical devices that support or replace basic vital functions provided emergency power supply in another way and recovery time of main emergency voltage resources are too long for them. When lettered, they will be marked with the letter V, since the circuits with the described method of securing the power supply are called very important circuits. [13]

Use of a particular diesel aggregate and its performance:

- Diesel generator CKD output 320 kW
- Consumption - 65 l / h
- Stocks - 400 liters in diesel tank + 2 drums of 200 liters each; 12 hours is sufficient, the diesel must be constantly replenished in the event of a power failure, fuel change: as a result of regular testing of the equipment, continuous change. The tests on the diesel aggregate are performed: 4x per month (once a week with no load or with load).
- Amounts produced: only minimal quantities during testing, no danger. Procedure and limitations in case of power failure. The energy is as follows - in the event of a power failure, the diesel generator starts to start automatically, when the complete connection is reached at maximum speed after approximately 45 seconds.
- Important circuits (green sockets), very important circuits (orange sockets, which were kept up by the UPS), lights, elevators and other important equipment will start to be supplied. If the unit is connected to the mains before it reaches maximum power, the generator may be overloaded and the machine may stop.

Summary of risks associated with the alternative source and their possible treatment:

- A low number of generators> Increase the number of generators
- Insufficient generator power> Increase generator power
- Insufficient fuel supply> Ensuring immediate fuel supply by an external company, construction of a fuel tank
- Backup generator failure> Acquisition of mobile generators

For the case of a blackout, a scenario is set in advance, according to which all medical facilities would proceed. These are evenly distributed throughout the Czech Republic. In the event of a long-term outage that cannot be bridged by a backup source, the option is to replace one medical facility with a representation of the closest possible facility of a similar type.

## 7 Discussion

If there is a power outage in a particular area, whether in the short or long term, people will notice it very quickly. In a simple breakdown, the impact of a blackout can be divided into several parts: impacts on people's lives and health, threats to the lives and health of the population due to reduced or interrupted electricity supplies or secondary crises. There is also a direct threat to the life and health of workers involved in the elimination of the consequences of damage to the electricity system, a direct threat to the life and health of power plant personnel. Less significant but still important is the damage or destruction of property and the environment. There is a risk of environmental contamination in production and storage facilities and their immediate vicinity, there is a risk of environmental pollution due to secondary crises. [14] The next step, now by prevention, is to verify the readiness of rescue services, selected critical infrastructure entities and other selected entities. One of the possible ways is through training to ensure the supply of electricity, heat, gas, drinking water, etc. It will provide training to ensure the basic living needs of the population, including their renewal. therefore, the exercise should simulate a power failure of at least 5 days, followed by an exercise gradual resumption of operations. [15] For the evaluation, analyzes of the process of finding critical points should be performed. Subsequently, such adjustments should be made to procedures and plans that the exercise would be beneficial for ensuring an emergency electricity supply in the event of a prolonged outage of the Czech

transmission system, as this risk represents a vulnerability of the state.

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