OPTIONS OF ADDRESSING POWER SUPPLY DISRUPTION IN THE CONDITIONS OF THE CZECH REPUBLIC: A CASE STUDY

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Abstract: The aim of the research described in the article is to examine the options of addressing power supply disruption in the selected sectors of infrastructure due to emergency situation: snowfall in the area of Český Krumlov and Prachatice districts in the Czech Republic on April 28, 2017. Based on the characteristics of climatic, meteorological and geographic data, consequences of power supply disruption are described with emphasis on the approach of the electricity distributor and the affected infrastructure (transport and communication networks - mobile operators) in selected sectors. Reflection on the intervention activities of the Fire Rescue Service units in making roads passable has been carried out. The article evaluates preparedness and intervention activities based on the case study of emergency situation management procedures related to the selected infrastructure and suggests recommendations for their improvement.

Keywords: emergency situation, electricity, transport, communication, blackout, mobile operator.

1 Introduction

According to the Intergovernmental Panel on Climate Change, climate change is manifested by a rapid increase in the number of extreme hydrometeorological phenomena [1]. Local and nationwide climatic and hydrological extremes have both short-term and long-term negative impacts on the safety of population, property, infrastructure, environment and the state as a whole. Extreme weather fluctuations can have far-reaching impacts on human society by the change in the performance of ecosystem services [2], and thus affecting the safe sustainable development. It is therefore essential not only to analyse the impacts of extreme phenomena, but also to predict and monitor their occurrence as well as identify the possibilities of adaptation and mitigation measures. This is the only way how to develop a disaster-resistant society and thus contribute to achieving sustainable development [3]. For this purpose, international institutions have begun to promote the fact that states, as responsible authorities, should define requirements for providing security and safety in the priority areas for which the greatest climate changes are assumed. These areas include forestry, agriculture, water management, healthcare, landscape, industry, energetics, emergency situations and population protection.

Simultaneously to the occurrence of extreme weather phenomena, the frequency and intensity of threats to the power system [4] increases. The increasing number of disruptions, whether by natural or anthropogenic threats, to major infrastructures has made it necessary to identify and establish protection and security requirements for the critical infrastructure sectors. Their disruption has a direct impact on the functioning of facilities and systems essential for the functioning of the state sustainable development and can demonstrate cascading effects on other sectors [5]. Therefore, it is very important to properly set up a disaster risk mitigation policy or strategy to promote competitiveness, sustainability and resilience of critical infrastructure entities [6].

Achieving sustainable development is burdened by a number of dynamic changes and impacts which society can become prepared for through crisis management. Crisis management consists of preparedness, response, recovery and mitigation phases [7, 8]. Implementation of disaster risk management forms the basis for successful crisis preparedness. This is based on a thorough risk analysis and evaluation and its subsequent management to support resilience. The first step towards effective crisis preparedness of the Integrated Rescue System components was the risk identification in the territory. In 2016, a Threat Analysis for the Czech Republic (CZ) [9] was conducted, which assessed the large-scale power supply disruption as an unacceptable risk. Unacceptable risks have been identified in the context of climate change – long-term drought, extremely high temperatures, rainstorm floods, heavy rainfall, extreme winds and floods. Subsequently, a threat analysis for individual regions of the Czech Republic was carried out by the methodologically consistent procedure (the total number of regions in the Czech Republic is 14). 13 out of 14 regions have identified the large-scale power supply disruption as an unacceptable risk. All regions in the Czech Republic assessed floods as an unacceptable risk, rainfall floods and long-term drought by 10 regions, extreme winds by 8 regions, extremely high temperatures by 5 regions, heavy rainfall by 1 region. The performed risk assessment became the basis for the preparation of a new type of plans and crisis plans of regions which represent the basic documentation of crisis planning.

The sources of the threat of power supply disruption are:

- Natural threats (bad weather, natural disasters),
- Accidental threats (resulting from system operation and maintenance, human factor failure and faults),
- Deliberate threats (including deliberate human activity, terrorism, crime) [10].

A detailed analysis of the electricity supply disruption in Europe [10] over a period of 15 years shows that the second most common cause is represented by natural threats followed by accidental threats. Even the authors of Duan Xianzhong and Su Sheng [11] list the causes of natural origin as frequent reasons for a power failure. Such manifestations of bad weather can be linked to the manifestations of climate change. Compared to technical defects, natural threats are more dangerous because of the virtually impossible prevention of extreme weather conditions. An example may be weather effects that cause tree uprooting and their subsequent fall on the transmission and distribution system lines.

The issue of power supply disruption is addressed in the scientific literature from several different perspectives. The topic of power outage is the subject of many studies in the field of power engineering. It represents a relatively new phenomenon from an interdisciplinary perspective of security studies and social sciences [12, 13]. The risk of power outages was investigated mainly from a technical point of view, where attention was focused on finding suitable technical and engineering solutions, how to prevent this phenomenon, or how to minimize the consequences of the outage to cause the least possible damage. Despite all efforts to design safer systems, we are still witnessing major large-scale emergency situations. As a rule, the view of the socio-technical risk management system is addressed, which includes several levels from legislators, through managers and work planners, to system operators [14, 15]. Disaster minimization is given attention in terms of communication, community health, preparedness of teams for correct decision-making process and management [16, 17, 18].

According to the authors' survey, a comprehensive evaluation of dealing with the consequences of power outage by specific entities in the area of Fire Rescue Services units, electricity distributors, security of railway transport and provision of mobile operator services has not been published at the international level. Scientific literature sources can be found that deal with the issue of power supply disruption by stabilising and manipulation in the transmission system [19, 20, 21]. Other authors focus more on possible causes, disaster prevention, health issues [22, 23, 24] and resilience, optimization and risk management in the society with regard to possible social and economic impacts [25, 26, 27, 28]. However, the results of research into the topic of the response of individual entities to power disruption in the form of a case study have not been published in the available scientific sources yet.

From the Czech Republic point of view, the low-voltage distribution system (0.4/0.23 kV) creates the largest part of the electricity system and is also the most vulnerable as it is led at outdoor support points (poles or columns) and is easily accessible without significant security protection against both risks of deliberate damage and natural risks. In the transmission system, security criteria n-1 or n-2 are implemented to prevent its disintegration. In terms of natural threats, the transmission system may be most affected by strong winds with velocity of above 100 km/h, landslides and icing.

Power supply outage, no matter where and when it happens, can be divided into the following four stages – Pre-condition, Origin, Chain of events and End [29]. In terms of crisis management, the third phase, Chain of events, is essential. During this phase, crisis management authorities and the Integrated Rescue System components must implement intervention and measures to mitigate the impact of the power supply outage on the population, taking into account their physiological needs and addressing the problem accumulation on interdependent infrastructures. The power supply outage can last from a few minutes to several weeks, depending on the nature of the blackout and the electrical network settings, so a distinction is made between:

- First stage – several-hour transmission system outage without serious damage,
- Second stage – several-day or week outage,
- Third stage – several-week or longer outage.

Short-term and long-term impacts of power supply outage are directly or indirectly manifested in economic areas [30], emergency services, mental health of inhabitants, social well-being, communication and information technologies, transport, public administration, services, water supply, waste and wastewater management, healthcare, heat and gas supply, banking, production, food supply and distribution as well as environmental. Communication between the intervening components with different roles and competences, private entities and population can be considered as the biggest challenge and the most complicated activity when dealing with power supply outage [31]. Providing communication is one of the elements of a resilient society which disruption reduces its functioning during an emergency situation [32].

The territory of the Czech Republic has not yet been affected by a major blackout, as shown in Table 1. Short-term and medium-term local power outages were reported in connection with floods, storms, snow calamities, icing, transformer station fires or accidental equipment damage (human error). Table 1 shows that the occurrence of the hurricane Xaver (year 2013) and the hurricane Herwart (year 2017) caused an increase in the average duration of one power outage in the electricity distribution at the customer (the so-called CAIDI indicator). The PREdistribution operator has the shortest power outage time. The reason is that it provides distribution only for the territory of the capital city of Prague and its surroundings and the distribution system has an interconnected structure. The distribution system operator E.ON Distribution has the longest period of power outage. Its activities comprise South Bohemia, South Moravia, partly in the Vysočina Region and the Zlín Region. It is an area with a total area of 26,500 km² [33], where the interconnection of the structure is lower and it has specific geographical and climatic conditions. The power supply after emergency situations of natural origin was mostly restored within 48 hours in the Czech Republic. Despite this, the safety of the population can be significantly affected during this period and it can cause economic damage of hundreds of millions CZK.

The article defines the causes and effects of power supply outage in its theoretical part. It compares interventions, intervention activities and damage on the example of hurricanes that hit the territory of the Czech Republic in the last two decades. The hurricane occurrence results in short to medium-term power supply disruptions, practical verification of crisis preparedness and real verification of the skills acquired during the exercises of crisis management bodies and Integrated Rescue System components. The practical part of the article explains the procedures of one of the Integrated Rescue System components and private entities when dealing with crisis situation on the example of extreme meteorological phenomenon, spring snow phenomenon, and its impacts on selected types of energy, transport and communication infrastructure. The article evaluates crisis preparedness and intervention activities of entities and points out the necessity of coordination of activities in dealing with an emergency situation.

Tab. 1. Average time duration of one electricity distribution disruption in the 2009–2018 period in the Czech Republic

Year	**2009**	**2010**	**2011**	**2012**	**2013**	
CAIDI [min]	138	125	113	113	133	
Distribution system operator						
ČEZ Distribution	138	112	103	101	129	
E.ON Distribution	159	172	157	175	161	
PREdistribution	49	76	72	79	68	
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
CAIDI [min]	119	119	117	156	114	124,38
Distribution system operator						
ČEZ Distribution	102	110	108	147	112	120,35
E.ON Distribution	180	156	158	199	124	142,48
PREdistribution	59	86	99	70	85	81,87

Source: [34]

Due to the high risk of a crisis situation incurrence in the power supply disruption, crisis management authorities and the Integrated Rescue System components pay increased attention to this danger and test their readiness for it through exercises. Since 2014, exercise aimed at the topic of power supply disruption has been carried out in 9 regions. In most exercises performed, extreme meteorological phenomena were the cause of power supply outage. On the basis of the resulting findings, regions try to eliminate shortcomings and improve their crisis preparedness.

The crisis management authorities together with the Integrated Rescue System components also gain experience with the power supply disruption from past emergency or crisis situations caused mainly by strong wind or hurricane. The most important were the hurricane Kyrill (year 2007), Emma (year 2008), Herwart (year 2017) and Sabine (year 2020). Table 2 shows that Kyrill was the strongest in terms of wind speed, however Herwart was the strongest in terms of incidents dealt with. Compared to the maximum number of events resolved on the first day of the Hurricane Kyrill (3,603), the number of events resolved on the first day at the Herwart hurricane was more than double (8,254). That is why Herwart was a much larger emergency event in terms of operational management, although fewer firefighters were deployed [35]. However, as a result of the hurricane Kyrill, an emergency state was declared, which did not happen after another hurricane. Even the example of the weakest hurricane Sabine shows that the total number of responses was 30 times higher than the long-term daily average. Increasing the accuracy and reliability of strong wind prediction, personnel and technical reinforcement of fire brigade units when declaring a strong wind danger for intervention purposes and informing the population with safety instructions leads to increased preparedness and minimization of losses caused.

Tab. 2. Comparison of the most important hurricanes in the Czech Republic

	Kyrill	**Emma**	**Herwart**	**Sabine**
Date	18. 1. 2007	1. 3. 2008	29. 10.2017	10. 2. 2020
Time of duration	4 days	2 days	3 days	2 days
Wind strength	216 km/h	169 km/h	182 km/h	184 km/h
Declared state	State of emergency (government of CR)	State of emergency (CEZ) and state of calamity in the energy sector	State of calamity in the energy sector (CEZ)	State of calamity in the energy sector (CEZ)

	Kyrill	Emma	Herwart	Sabine
Number of emergency calls	48,833	27,900	29,305	13,000
Number of events resolved by fire brigade units	7,729	4,258	9,925	5,488
Maximum of events in 1 day 1	3,603	3,138	8,254	3,988
Firefighters deployed	33,822	11,500	13,000	-
Firefighters injured	26	11	5	0
Number of dead	6	2	4	1
Reported insurance claims (CZK)	2.25 billion	1.4 billion	1.45 billion	0.59 billion
Damaged wood in the forests (million m^3)	6	2	1.7	0.95

Source: modified source [35, 36]

2 Materials and Methods

The aim of the article is, using a case study, to research the options of addressing the impacts of power supply disruption due to snowfall emergency situation in the Český Krumlov and Prachatice districts (part of the South Bohemian Region) in the Czech Republic on 28 April 2017 on the selected areas of infrastructure. The subject of the research into the selected areas of infrastructure was the response of the electricity power distributor, the activities and interventions of the Fire Rescue Service units, the specifics of providing railway transport security and the functionality of communication in the network of mobile operators. The research does not address the impacts of power supply disruptions to areas other than those listed due to the unavailability of data or the unwillingness to provide data. A partial objective was to carry out a qualitative evaluation of crisis preparedness and intervention activities and to propose recommendations for their improvement on its bases. Causal climatic and meteorological conditions, which caused the power supply disruption are characterized. In order to achieve the objective, specific activities were qualitatively analysed from the point of view of the electricity distributor, transport and communication with an emphasis on mobile operators. Analysis was used in the research as a method based on the decomposition of the whole into elementary parts, it is a method of examining more complex facts by their dissolution into simpler, basic units. The aim of the analysis was to identify the essential and necessary properties of the elementary parts of the whole and to identify their essence and regularities.

The research was performed as a case study in the conditions of the Czech Republic. From the research point of view, it is therefore a research limitation focusing only on the affected area of the Český Krumlov and Prachatice districts.

Information was from the methodological point of view obtained mainly from scientific literature research, from guided interviews with representatives of the individual organizations concerned and from internal sources of selected subjects. In the theoretical part of the article, the comparison method was used. The comparison was used to compare selected impacts of power supply outage, interventions and intervention activities carried out by the Fire Rescue Service and municipality units of the voluntary fire brigades during the hurricanes affecting the whole area of the Czech Republic, where there was also a local power supply disruption and the declaration of the state of calamity in the energy sector. Descriptive scientific methods and interview methods were used in the practical part which were especially predicting the occurrence of one phenomenon based on the occurrence of another phenomenon. An important method for obtaining information and fulfilling the aim was a method of guided interviews. The interview method is based on direct questioning, i.e., on verbal communication of the researcher (authors) with the respondent. During the interviews, representatives of the entities concerned were interviewed in order to find out real information about the course of the emergency situation. Furthermore, the synthesis as a process of joining several parts into one whole, served to interconnect particular pieces of knowledge.

The research was carried out as a systematic investigation into the phenomena in order to obtain knowledge that describes and explains the current readiness of selected organizations for the consequences of power outages. The research part included a systematic process of gathering information, synthesizing already-existing knowledge and achieving an increase in the knowledge [37]. The aim was to get a unified view of the subject of the study – options of addressing and the readiness of selected entities for power failure. On the one hand, the aim was to separate individual areas of security issues - civil protection, on the other hand, these individual areas were kept as much as possible in the context of other areas.

3 Case Study

Practical part of the research described in the article defines the geographical, climatic and meteorological conditions that led to snowfall in an atypical month of April 2017. It evaluates the response of affected entities and proposes recommendations based on the results of impacts on the energy, transport and communication infrastructure.

The power supply disruption in the low-voltage distribution system occurred on 28 April 2017 in part of the South Bohemian Region, the Český Krumlov district (1,614 km2) and the Prachatice district (1,375 km2). Average population density in the South Bohemian Region is 63.3 inhabitants/km2. The lowest population density per km2 is reported by the Český Krumlov Region, where the average population density per km2 is 37, which ranks it on the last place not only in the South Bohemian Region but also within the Czech Republic as a whole. The average population density in the Prachatice district is 37.6 inhabitants/km2. The reason for the low population density in the territory of these two districts is the existence of the Šumava mountains and the Šumava foothills with extensive continual forest areas. Due to the low population density, the impact of the power supply outage affected only a relatively small part of the population.

The climate in the evaluated territory can be characterized as the climate of the northern temperate zone. The temperature and precipitation regime tend to be influenced by terrain unevenness and passes from the slightly template areas in lower altitudes into the cold area.

At the beginning of the monitored period on 25 April 2017 the weather in the Czech Republic was relatively warm, the temperature ran from 10 to 16 °C and it was raining even in the mountains. It was gradually getting colder, at altitudes above 1,000 m above the sea level, the temperature on 26 April and 27 April 2017 was just around zero (-1 °C; +1 °C), in lower altitudes 2 to 5 °C, mixed precipitations or alternately snowfall occurred both in lower and middle altitudes. The snow was quite wet and heavy, it was melting in the lower and middle altitudes, however in the evening with a drop in temperature the continuous snow cover was formed in the lower and middle altitudes and the snow depth was continually increasing. From 26 April 2017 8 o’clock a.m. CET to 27 April 2017. 8 o’clock a.m. CET, the daily total rainfall was in the monitored area of Prachatice and in the Český Krumlov Regions at 9 to 20 mm, while in the mountains with altitude the water value of snow cover was increasing towards total rainfall. The temperature on 28 April 2017 at night and in the morning dropped to zero even in the altitudes of around 400 m above the sea level and in the morning, it was snowing in all altitudes. The snow cover continued to be damp, heavy and contained large percentage of water. Heavy snow caused extensive damage to spring vegetation, foliage and pine trees. With the increasing altitude the length of snowing was prolonging and over 1,000 m above the sea level it was more or less snowing all day. The highest depth of the snow cover in these altitudes appeared around midnight from 28 April to 29 April 2017. The characteristics of the described development of meteorological conditions on the whole territory can be seen from Table 3.

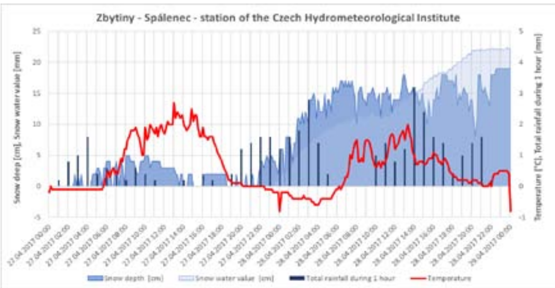
Tab. 3. Development of climatic and meteorological conditions on 27 April and 28 April 2017

Date	Weather	
	Day	Night
27/4/2017	Mostly cloudy, snowing -1 °C to +1 °C	Snowing, sleeting 0 °C
28/4/2017	Snowing +4 °C	Snowing 0 °C
	Snow cover	
	Altitude	Height
27/4/2017	500–700 m	1–5 cm
	over 1 000 m	10–20 cm
28/4/2017	500–700 m	2–5 cm
	over 700 m	10–25 cm

Source: authors‘ own

Detailed development of conditions at the selected mountain meteorological station Zbytiny - Spálenec of the Czech Hydrological Institute in the affected territory is graphically depicted in Figure 1. The station is equipped with a snow-measuring cushion that automatically collects the monitored parameters - temperature, total rainfall sum, total snow cover depth and snow water value.

Fig. 1. Development of selected indicators at Zbytiny station on 27 April and 28 April 2017



Source: authors‘ own processing according to CHMI data

Due to the advanced spring vegetation period, when the deciduous trees were already swollen and with small leaves, the whole trees were uprooted or their tops and branches were broken due to the very wet and heavy snowfall. Many broken trees disrupted the power supply, or blocked roads and railways.

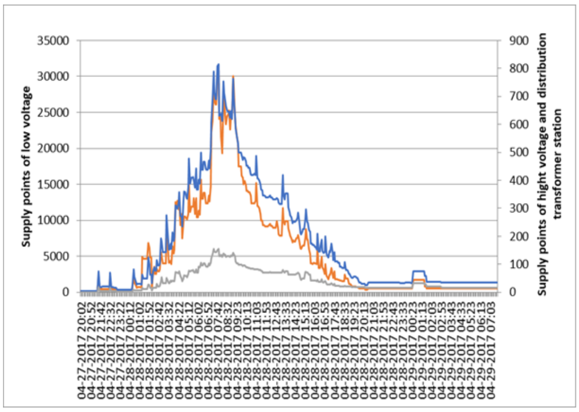
3.1 Power supply disruption in the affected area

In the evening on 27 April 2017, an increased failure rate began to occur at the high voltage level in the R 110/22 kV Větřní power supply district of Český Krumlov. After midnight there was an increase in the failure rate in the area of switching stations R 110/22 kV Vimperk and Prachatice, which supplies the territory of the district Prachatice. The main cause of increased failure rate was heavy snowfall and rain. Wet snow caused the above-mentioned falls of mainly deciduous trees on the power lines, with consequent damage to the equipment of distribution transformer stations, mainly insulators and high-voltage conductors. The culmination of the emergency situation in terms of the power supply outage appeared in the morning on 28 April 2017. The most affected areas were: Krumlov, Lipno, Kaplice, Volary, Prachatice and Churáňov areas.

Elimination of the consequences of the calamity was complicated by the situation in traffic, where there were impassable roads in the affected area and in some places the Police of the Czech Republic closed traffic due to impassability or danger of trees falling on the roads. During the daytime of 28 April 2017, the damaged sections were continuously restored, distribution station damage was removed and the systems were energized. The work was terminated between 8:00-9:00 p.m. for the sake of safety of field workers and for keeping safety breaks. During the night on 29 April 2017, no further failures occurred. In the morning of 29 April 2017, the remaining failures on the high and low voltage level were eliminated. Overnight from 28 April to 29 April 2017 the following distribution transformer stations remained out of service:

- Světlík (VET) – 8 DTS, municipality Světlík,
- Dvořiště (VBR) – 1 DTS, municipality Mnichovice,
- Smědeč (PRA) – 10 DTS, municipalities Křišťanov, Spálenec, Majdalena.

Fig. 2. Number of switched off supply points of distribution transformer stations



(Note: low voltage – orange colour, high voltage – grey colour, distribution transformer station – blue colour)
Source: authors‘ own processing according to E.ON Distribution data

About 65 operations workers participated in the elimination of the consequences of the emergency situation. These were mainly fitters and dispatchers. In addition, other technicians participated in managing work organization. Due to the extent of the emergency situation, the crisis staff of the E.ON company did not meet [38]. Calamities of this extension are solved by standard decision-making processes and competences of individual managers.

3.2 Interventions of the Fire Rescue Service units

South Bohemian Region Fire Brigade and Volunteer Fire Brigade units were clearing trees, that had fallen or were uprooted under the weight of heavy wet snow, from the roads. These were so-called multiple interventions, when firefighters dispatched to one event cleared more fallen trees within one intervention [39].

Most of the multiple interventions were carried out in the area of Prachatice – Volarsko and Český Krumlov. In the evening of 27 April – morning 28 April 2017, the fire brigade units were dispatched to remove fallen or uprooted trees in the Prachatice district 79 times and in the Český Krumlov district 63 times. On 29 April 2017, firefighters in the České Budějovice area were busier in the morning. In the most exposed period, the incidents were reported every two minutes from the emergency lines 112 and 150 to the Operational and Information Centre of the Fire Rescue Service of the South Bohemian Region. In all cases, these were trees fallen on the roads or railways. After seven o'clock in the morning on 29 April 2017 the situation calmed down.

There is no information that a member of the Fire Rescue Service of the South Bohemian Region or Volunteer Fire Brigade units was injured in connection with an emergency situation. From the point of view of the fire protection, it is necessary to point out that the power outage also had some influence on the operation of some fire safety equipment (for more information on the impacts on the fire safety equipment failure in [40]).

3.3 Impact of the emergency situation on rail transport

There are no electrified railway lines in the area, except for the Rybník – Lipno nad Vltavou – Horní Dvořiště track. With regard to the meteorological forecast of the Czech Hydrometeorological Institute and continuous monitoring of the situation, appropriate measures were taken. Ride of trains was in the so-called "On Sight Regime". This meant adapting (usually slowing down) the immediate train speed according to the engine driver's opinion. In the area of Český Krumlov and Prachatice the trees fallen on the railway limited the traffic. Trains were always been able to safely stop in front of the obstacle (fallen tree) that occurred in the clearance profile of the rail track body. No damage to the health of transported passengers or extensive material damage occurred.

Removal of fallen trees from the clearance profile of the rail track was performed by employees of the Strakonice railway station in cooperation with the Fire Rescue Service unit of the Railway Infrastructure Administration and other fire rescue units involved. Some trains were accompanied at the engine driver's cab by employees equipped with sawmills intended to promptly remove dangerous obstacles on the track. However, no damage to the railway infrastructure in connection with the emergency occurred. Table 4 shows the railway tracks and full recovery times without restrictions during 28 April 2017.

Tab. 4. Overview of putting individual tracks into operation.

Track section	Time of putting into operation on 28 April 2017
Volary – Černá v Pošumaví	7.10 a.m.
Černý Kříž – Nové Údolí	7.40 a.m.
Rybník – Vyšší Brod klášter – Lipno nad Vltavou	12.33 p.m.
Vimperk – Čkyně	2.25 p.m.
Volary – Vimperk – Čkyně	4.55 p.m.
Volary – Prachatice	5.45 p.m.
Kubova Huť – Lipka	10.15 p.m.

Source: authors' own

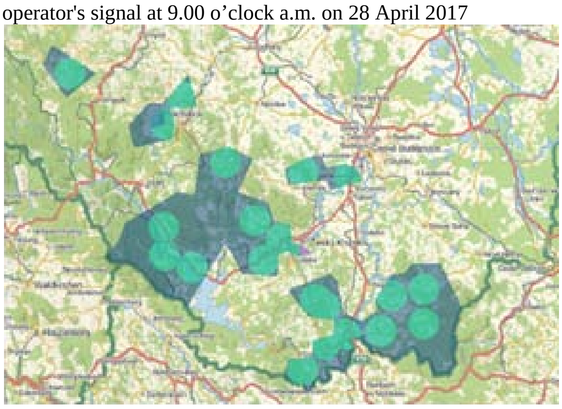
3.4 Influence of emergency situation on signal transmission of mobile operators

Relationship between the power outage and the renewal process can also be documented at the outages of mobile operators' transmitters. In order to carry out communication using a mobile phone, it is necessary to have the entire infrastructure in operation, from the telephone set to the Base Transceiver Stations, controllers to the main exchange. The main element of the whole system is the power supply of the base stations as they are not backed up to spare sources. Other elements are sufficiently secured in the event of a power outage.

Figures 3–5 graphically show the signal loss of the base stations of the mobile operator during the daytime of 28 April 2017. In the beginning, the signal loss of the base stations covered a significant part of the monitored area. The gradual renewal took place on the basis of renewed power distribution from the distribution network or, in some cases, also through the use of a substitute mobile source. This solution was used mainly for the coverage of the mobile operator's signal on a class I road in order to provide road safety. The decreasing number of uncovered areas by the mobile operator's signal (Figures 3–5) can also be seen from the timeline of power supply recovery (Figure 2).

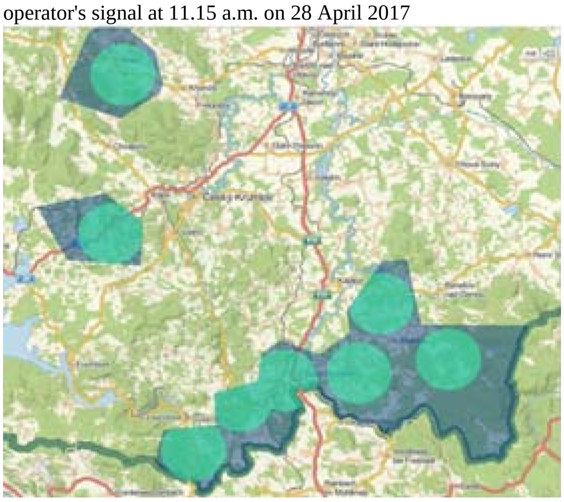
Operation of a uniform alert and notification system to warn the population in the event of emergencies and crisis situations was dependent on the type of sirens used in the area. In the case of installed rotary sirens, their malfunction was obvious, as they are permanently dependent on power supply. Electronic sirens have backup batteries with a maximum operating time of 72 hours. These enabled to provide information to the affected population.

Fig. 3. Areas with non-functional transmission of the mobile operator's signal at 9.00 o'clock a.m. on 28 April 2017



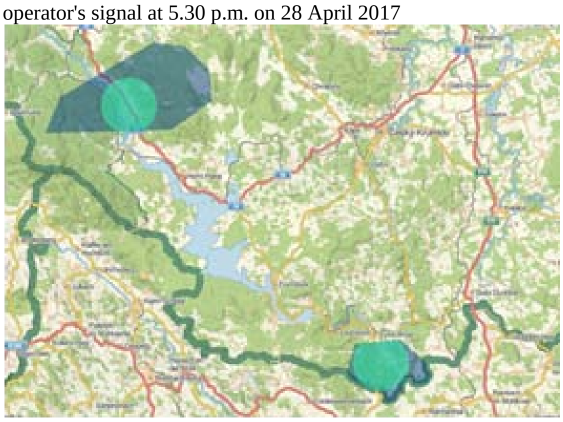
Source: own processing according to the data provided by the mobile operator

Fig. 4. Areas with non-functional transmission of the mobile operator's signal at 11.15 a.m. on 28 April 2017



Source: own processing according to the data provided by the mobile operator

Fig. 5. Areas with non-functional transmission of the mobile operator's signal at 5.30 p.m. on 28 April 2017



Source: own processing according to the data provided by the mobile operator

4 Results

Both the threat of snow calamity and the threat of power supply disruption were identified for the region by the risk analysis. When assessing the risk, the threat of snow calamity was assessed as acceptable. This means that it was not expected to declare a crisis situation and a summary of measures to carry out rescue and liquidation work to avert the threat was developed in the regional emergency plan. In the case of power supply disruption, however, the situation was different. The threat was assessed as unacceptable in the area of the region and included in the regional crisis plan. The components of the Integrated Rescue System were equipped with the technology for the elimination of an emergency situation and the members underwent both theoretical and practical training. From a formal point of view, preparedness was fulfilled. In terms of practical training of crisis preparedness, the crisis management authorities and the Integrated Rescue System components of the South Bohemian Region were preparing in 2017 for the Blackout 2017 exercise to be held on 4-5 December 2017. The exercise planning phase was one of the most crucial stages. It included detailed analyses of the impacts of the power outage, including prioritization of priority emergency connections, what infrastructure activities and elements must be maintained and how to address impacts in each area. Both the preparation of the exercise and the results of the exercise showed weak points. They become a challenge to carry out further steps towards increased preparedness, provision of resources for preventive and mitigating measures to deal with emergency situations with power supply failure.

The knowledge and experience in dealing with an emergency situation of power supply outage and Blackout 2017 exercise was incorporated into the Crisis Plan of the South Bohemian Region, in particular into the power supply outage plan. The crucial task was to describe and propose communication methods in the case of the failure of traditional means of communication by means of analogue radio communication and messengers (distribution and transfer of information by a natural person). The issue of power supply disruption and transfer of experience was the topic of an international workshop with participants from the Czech Republic and Austria in 2019. The innovative aspect as well as the contribution of the presented study results lie in the specific analysis of the authentic emergency situation, presentation of the interconnectedness of its impacts on individual entities and evaluation of activities in specific areas (Fire Rescue Service units, communication possibilities in the mobile operator's network, impact on rail transport) within the case study.

The study confirmed that practical solution to the emergency situation and exercise with power supply outage topic are necessary for professional preparedness of the staff and quality technical and material equipment. Professional preparedness places demand on the affected entities and crisis management to correctly understand the system interconnectivity, technical possibilities of solutions, including current assessment of the priority concerning electricity consumers. The technical and material equipment consists not only of the required equipment of rescuers, distribution system operators, but also of the preparedness of both mobile and permanent back-up power sources and of the technical preparedness of connection points for alternative power supply for the subjects important for providing basic functions in the territory. An important part is represented also by the provision of fuel for rescuers and back-up power sources.

Another outcome resulting from the implementation of this study was that interventions by both professional and volunteer fire brigade units were carried out according to standard procedures. Effectiveness of the dispatched intervention activity has been evidenced by the increased implementation of multiple interventions which helped to speed up the reconstruction of transport and energy infrastructure, followed by the communication infrastructure. The proposal for fire rescue brigade units in case of prediction of extreme meteorological phenomenon occurrence shall be increasing the number of staff at all stations. The results of the emergency analysis show an enormous increase in the number of calls to emergency line. When declaring a warning by the Czech Hydrometeorological Institute for high or extreme degree of danger, especially for wind, snow, icing and storm phenomena, we recommend to increase the number of emergency lines operators by at least 50% compared to normal situation in order to avoid overloading and promote smooth handling of emergency calls.

The evaluation of the situation showed the need for timely instructing the engine drivers to operate in “On Sight Regime”. Timely notification and active operation of the Fire Rescue Service of the Railway Infrastructure Administration and other fire rescue units involved is essential for providing rail safety and minimizing losses. From the standpoint of preparedness, it is essential to have enough trained personnel and technicians ready at hand who would remove fallen trees or power lines on the rail track.

Recommendation resulting from carrying out the study in the area of railway transport in the affected area is to restore the power supply for the Rybník – Lipno nad Vltavou – Horní Dvořiště track as it is an international railway line between the Czech Republic and Austria. Otherwise it is necessary to introduce a substitute bus service, which however, may be delayed due to poor road passability. In the event of a major power supply outage, for non-electrified railway lines, the operator must provide personnel, fuel supply, process alternative variant train traffic diagrams, add back-up power sources to designated railway stations, provide level crossing safety equipment and support for the crossing barriers in open position (which is crucial for the priority roads or as required by the Integrated Rescue System components). The operation of the level crossing interlocking equipment has spare power sources. Rechargeable batteries have a service life of only 3-6 hours, after which the level crossing signalling equipment stops working. In order to reduce accidents at level crossings at the time of power supply disruption, it is necessary to inform the drivers to be more careful when crossing level crossings and the engine drivers must provide an audible signal from the train before approaching the crossing.

It is clear from the analysis and experience gained by addressing this specific emergency situation that in case of a medium-term power outage in the area of communication, the Digital Radio Network of the Ministry of the Interior of the Czech Republic - PEGAS and the analogue radio network of the Fire Rescue Service of the South Bohemia Region which would provide communication between selected basic components of the Integrated Rescue System and crisis staffs of municipalities with extended powers would keep working, however in a limited extent. In the current situation of digitization and widespread use of mobile phones the problem lies in the communication infrastructure of mobile operators. As mentioned above, functional operation of all elements is essential to provide communication. Base stations are the weakest elements of the whole infrastructure. It is recommended that mobile operators, especially at base stations and other vulnerable infrastructure elements, build up back-up power sources or enhance the capacity of rechargeable batteries. This is because mobile phones represent an essential tool for informing the population about imminent or emerging dangers, as well as means for the population how to contact the emergency line. The failure of the mobile operator can complicate the saving of human lives. In the case of the researched situation and area, the advantage was that the failure of the mobile operator appeared in low-populated areas.

The carried-out analysis dealing with the emergency situation in the Prachatice and Český Krumlov districts showed that the readiness to resolve the medium-term power supply outage in a limited area is at sufficient level. Individual entities cooperated and exchanged information. Media coverage of the emergency situation at the nationwide level also contributed to the awareness among the population, although none of the crisis states was declared and individual authorities managed the resolution of the emergency situation by their own means and forces.

5 Conclusion

Achieving territorial resilience as a tool for promoting sustainable development is not possible without public and private sector authorities being aware of the responsibilities for preventing emergencies and crisis situations, preparedness, response and recovery. Power supply disruption regardless of the source of the threat represent one of the greatest security risks of present day. Dependence of man and society on electricity supplies makes us highly vulnerable to the threat. Even short-term power supply disruptions create technical and operational problems with impacts on all economic sectors, e.g., healthcare, accommodation services, water supply, food production and sale [41]. Resilience in connection with the power supply disruption must also include self-sufficiency and preparedness. Building them up on the side of stakeholders is time and financially demanding or even unreachable in this case. Preparedness and readiness checking help to estimate the extent of impacts, plan resources and propose specific countermeasures. This approach will provide greater flexibility, interoperability, increase security and independence compared to simply relying approach on the Integrated Rescue System components and crisis management authorities. Otherwise, serious security and economic impacts, a slowdown in regional development and other regional problems may occur [42, 43].

A repetition of a comparable emergency situation cannot be excluded due to the manifestations of climate change. Extreme meteorological phenomena with similar or even greater impacts than the analysed situation on 28 April 2017 affect parts or the whole territory of the Czech Republic more often. In the first step, it is necessary to strengthen the role and capabilities of the Czech Hydrometeorological Institute in relation to the prediction and subsequent monitoring of these phenomena occurrence. Both the society and individuals need to keep preparing to address short and long-term power outages. Preventive preparation of individuals must be based on making necessary preventive provisions of basic food, water and medicine for personal use. At municipal, regional or national level, society must be able to maintain communication flows between crisis management authorities and the Integrated Rescue System, as well as towards the population and other stakeholders. The possibility is to use emergency (permanent or mobile) power sources, however especially in pre-reflected prepared basic procedures. This also means providing adequate supply of fuel quantities.

The presented and analyzed example of an emergency situation, snowfall from 28 April 2017, when a medium-term power supply outage occurred in the relatively limited territory of the region, represents one of the potential threats to the safety of the society. Based on the characteristics of climatic and meteorological causes of the emergency situation occurrence, the intervention activities of Fire Rescue Service units as well as private entities in the field of energy, transport and communication were described. Due to the unavailability of information, it was not possible to present other areas affected by power outage in detail, as the willingness to provide this information by relevant stakeholders was missing. Measures for prevention and mitigation in the case of repeated threats in the researched areas were proposed. The results of the evaluation of the emergency situation show that the restoration of the technologies of mobile operators is dependent on the power supply and it is necessary to strengthen their resilience by means of back-up energy sources. The components of the Integrated Rescue System did not have to address the impact of a large extent on the population due to the less populated, mainly rural areas.

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