PhDr. Tomáš Fröhlich, DiS.
SECURU s.r.o.
Czech Technical University in Prague
Faculty of Biomedical Engineering
Department of Health Care and Population Protection
Ing. Jiří Slabý, Ph.D.
SECURU s.r.o.
doc. Mgr. Zdeněk Hon, Ph.D.
Czech Technical University in Prague
Faculty of Biomedical Engineering
Department of Health Care and Population Protection
prof. MUDr. Leoš Navrátil, CSc., MBA, dr.h.c.
Czech Technical University in Prague
Faculty of Biomedical Engineering
Department of Health Care and Population Protection

Evaluation of the Territory Resilience to Extensive Power Disruption

A problem context

Nowadays the electric energy represents an essential commodity on a national and also international level. The reliable and secure power delivery is the key element on which all human activities and, in many cases, human lives are directly dependent. Electricity is important for numerous critical infrastructures, including but not limited to the gas infrastructure, water supply, telecommunications, financial services, security services, public health, agriculture, and transportations systems. Following a blackout, losses in electricity delivery can result in loss of service for numerous customers that may extend significant periods.[1] There is the important infrastructure, which needs to be permanently 24 hours a day, 7 days a week available.[2] An outage of this infrastructure would have massive impacts raging from less important, e.g. habitants' discomfort to very serious e.g. property damage, pollution of the environment or even people casualties. Pescaroli et al.[3] identified multiple possible impacts ranging from those which pose a direct threat to health (e.g. increased traffic accidents, difficulties distributing medicines, loss of medical records, water shortages, spoilage of foods, public disorder) to indirect impacts (e.g. loss of financial services, reduced working hours, transport disruption, loss of communications) and operational challenges for

[1] CASTILLO, Anya. Risk analysis and management in power outage and restoration: A literature survey. *Electric Power Systems Research*, vol. 107, pp. 9-15. ISSN 0378-7796. DOI: 10.1016/j.epsr.2013.09.002.
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government agencies (e.g. reduced ability of personnel to attend work, loss of communication between agencies, difficulties in procuring essential supplies).

In the case of an extensive long-term power outage (also referred to as a power blackout), it is not possible to fulfil the demand of all end users. In such a case, it is necessary to intelligently route disposable energy to the important infrastructure objects that secure life-important functions for the inhabitants of the impacted area. Those important infrastructure objects need to be preferentially supplied. This article focuses on a methodology on how to identify the life-important-service-providing infrastructure objects.

Readiness of territories against a power blackout

The phenomenon of a power blackout slowly emerged as the electrical power grid widely spread across territories, which in the case of the Czech Republic happened around the turn of the nineteenth and twelve centuries. The importance of the power blackout (mostly measured by the massiveness of the impact) increased over time as the development of technology accelerated. Today's vast usage of power-hungry devices and omnipresent dependence on information technology ramped up this risk to the very top of the ladder. The Czech power grid was near to collapse at the end of 2011. Between November 25th and December 16th, 2011, the consumption rose from nominal 1000 MW to 3500 MW. The reason is accounted for several factors. Wind power plants in north Germany are by design very volatile in production and energy they produce is mainly routed via the Czech Republic grid to Austria; a dramatical increase in production of photovoltaic power stations in Germany; continuous shutdowns of nuclear reactors in Germany; and also the substantial trade volumes on the energy market. The second critical situation when the Czech power grid was overwhelmed happened in late 2014 when there was again extensive electricity production of the wind powerplants in north Germany.[1] So far, the latest critical situation of this kind happened in January 2021 due to the cascading failures in Croatia, Serbia and Romania. At that time the European power grid split into two parts and power plants across the whole region had to restrict reactors' rotation.[2]

Based on the above-mentioned examples and other resources (The Threat analysis of the Czech Republic or several performed field exercises simulating power outage) it turned out that the readiness towards power blackout is not new. To examine the current status and actual preparedness of territories against the power outage the analysis and mapping were performed. This was divided into several steps:

- An analysis of the available legislation in the field of territory resilience to critical events with a focus on power outages.

[1] *Technicky týdeník – Přenosová soustava ČR pod tlakem: masivní přetoky energie z Německa* [online]. Business Media CZ. [2021-03-03]. Retrieved from: https://www.technickytydenik.cz/rubriky/archiv/prenosova-soustava-cr-pod-tlakem-masivni-pretoky-energie-z-nemecka_18297.html.

[2] *Krátkodobý rozpad synchronní zóny a pokles kmitočtu neohrozil provoz přenosové soustavy ČR* [online]. ČEPS, a.s. [2021-04-05]. Retrieved from: https://www.ceps.cz/cs/tiskove-zpravy/novinka/kratkodoby-rozpad-synchronni-zony-a-pokles-kmitoctu-neohrozil-provoz-prenosove-soustavy-cr.

- Research of approaches and methodologies dealing with priority supply of electricity in case of unexpected events.
- Research of approaches how to identify and assess critical objects within a territory.
- Conduction of a field research to analyse real behaviour and used approaches of municipalities during long-term power failure and how they prioritize power delivery.

The field research, which was the critical part of the mapping is discussed in detail later in this article.[1]

The field research

The conducted field research was the main part of the research because it identified real requirements and commonly adopted approaches to how the power outage situation is handled in real. The respondents were gathered from representatives of municipalities and country regions to which jurisdiction the critical situations agenda falls under.[2,3,4] There is a role called "secretary of the security council", which is stated in the legislation. The respondents were carefully selected within this group. This role should possess the necessary information to handle the power outage situation, or at least has the right to request such information if not available in advance. The field research had two parts - the questionnaire and a moderated interview. The focus of the field research was to determine whether there are crisis procedures in place and if the respondents evaluate objects in the territory. If the evaluation takes place what methodology is being used and how the criticality of the objects is being calculated. Overall, 14 representatives of country regions in the Czech Republic were contacted. 100 % of respondents replied to the questionnaire and 11 respondents also agreed on the interview.[5]

The results of the field research

The outcomes of the field research identified several different approaches to the problem. For this article, only relevant data regarding the power outage domain were selected. The main discovery is that each country territory evaluates its belonging objects differently, thus the resulted list of objects sorted by the criticality comes out different. The respondents confirmed that they conduct the evaluation subjectively based on several criteria. There were identified several common parts, which one might consider as "a standard", but when investigating deeply it turned out that even

[1] FRÖHLICH, Tomáš; SLABÝ, Jiří; HON, Zdeněk. A. An analysis of the security requirements of a selected area during a power outage and determination of objects of the utmost importance. In: KAVAN, Š. (eds.) *International Conference Safe and Secure Society 2020*. Conference proceeding. České Budějovice: College of European and Regional Studies Czech Republic, 2020, pp. 28–34. DOI: 10.36682/ssc_2020.

[2] Ústavní zákon č. 1/1993 Sb., Ústava České republiky, ve znění pozdějších předpisů.

[3] Zákon č. 129/2000 Sb., zákon o krajích (krajské zřízení), ve znění pozdějších předpisů.

[4] Zákon č. 131/2000 Sb., zákon o hlavním městě Praze, ve znění pozdějších předpisů.

[5] FRÖHLICH, Tomáš; SLABÝ, Jiří; HON, Zdeněk. A. An analysis of the security requirements of a selected area during a power outage and determination of objects of the utmost importance. In Kavan, Š. (eds.) *International Conference Safe and Secure Society 2020*. Conference proceeding. České Budějovice: College of European and Regional Studies Czech Republic, 2020, pp. 28-34. DOI: 10.36682/ssc_2020.

though the terms used seems the same, they are treated differently by individual parties. There is currently no legislation that would lay down the common process, criteria, methodology and determine exact terms and their meanings.[1]

The questionnaire revealed that 11 regions (79 %) already have a list of critical objects for priority power supply. This list was created by the respondents (representatives of the country regions or large municipalities) in cooperation with the representatives of a respective fire brigade local headquarters. In several cases also representatives of the corresponding power distribution company were involved. All respondents confirmed in unison that missing common legislation in this area forced them to invent their approach based on an experts' guess and experience. Such evaluation took into consideration local specifics and regional knowledge of the evaluating experts. The focus was to identify objects which are involved in the main processes happening within the respective territory, ensuring human safety and primary functions. 43 % (6 regions) of the respondents had the list of identified critical objects sorted (prioritized). However, the prioritization again was performed individually based on different aspects. The rest of the respondents (57 %, 8 regions) were not prioritizing the objects at all.

Less than half of the respondents (43 %, 6 regions) keep relevant attributes of the objects, e.g.:

- Power requirements;
- Existence of additional power supply, output power;
- Max length of operation of the additional power supply;
- Consumption of fuel of the additional power supply;
- If and how the supply of fuel is secured;
- Fuel capacity of the additional power supply.

The structure of attributes varied based on local specifics. Respondents also confirmed that the acquisition of the values was performed just once and since then not updated. The acquisition was performed by the officials from corresponding fire brigade local headquarters with one exception - the objects governed by the state territory representatives. In this case, the attributes were acquired by the officials from municipalities themselves. In 7 cases (50 %) attributes were not gathered at all and in 1 case (7 %) this question was not answered.

More than one-third of the respondents (36 %, 5 regions) expect to utilize the island mode of operation in case of a mass power failure and 64 % (9 regions) replied that they do not have resources in place to secure such type of operation. However, respondents from the second group stated that they consider the island mode of operation as an effective mitigation procedure in case of a mass power failure and will add the preparation of a such plan to their upcoming agenda.

[1] Note: During the time of this field research the government of the Czech Republic released resolution nr. 710 from October 8th, 2019 introducing the methodology how to identify critical objects with priorities within the territory in the context of power supply failure. This resolution had no connection to this research and was developed in parallel. Sadly, the introduced methodology is not detailed enough to fully harmonize approach and meaning of important variables in this field, yet it is a very well perceived step towards standardization.

The model for critical objects evaluation

So far, the widely adopted approach to the identification of critical objects and assessing their criticality in the context of mass power failure is isolated not considering broader context. This approach is applicable but has several limitations. On the one hand side, it requires a powerful backup energy source located within the evaluated territory. On the other hand, this energy source might not be sufficient to satisfy all listed critical objects. Moreover, this list might not contain all critical objects necessary to preserve territory-critical processes, which will be revealed during the crisis.

To avoid such a situation, it is necessary to determine two basic attributes. First, to ensure basic human life requirements of inhabitants and second, to secure the main functions of the impacted area.

To determine basic human requirements, it is possible to use widely known and adopted Maslow's hierarchy of needs. It is an idea in psychology proposed by Abraham Maslow in his 1943 paper “A Theory of Human Motivation” in the journal Psychological Review. Maslow's hierarchy of needs is used to study how humans intrinsically partake in behavioural motivation. Maslow used the terms “physiological”, “safety”, “belonging and love”, “social needs” or “esteem”, and “self-actualization” to describe the pattern through which human motivations generally move. This means that for motivation to arise at the next stage, each stage must be satisfied within the individuals themselves. Maslow's hierarchy of needs is often portrayed in the shape of a pyramid with the largest, most fundamental needs at the bottom and the need for self-actualization and transcendence at the top. To pursue intrinsic motivation higher up Maslow's hierarchy, physiological needs must be met first. This means that if a human is struggling to meet their physiological needs, then they are unlikely to intrinsically pursue safety, belongingness, esteem, and self-actualization. Physiological needs include air, water, food, sleep, health, etc. The basic human life requirements of habitats in the territory can be interpreted as needs that are needed to secure above mentioned physiological needs. The main functions of the impacted area represent processes connected to public administration. If these processes are missing the area cease to fulfil its mission and becomes just an empty territory shell.

The newly developed methodology for the identification and evaluation of critical object within the territory, which is one of the research outcomes, is based on a process approach (see Figure 1).

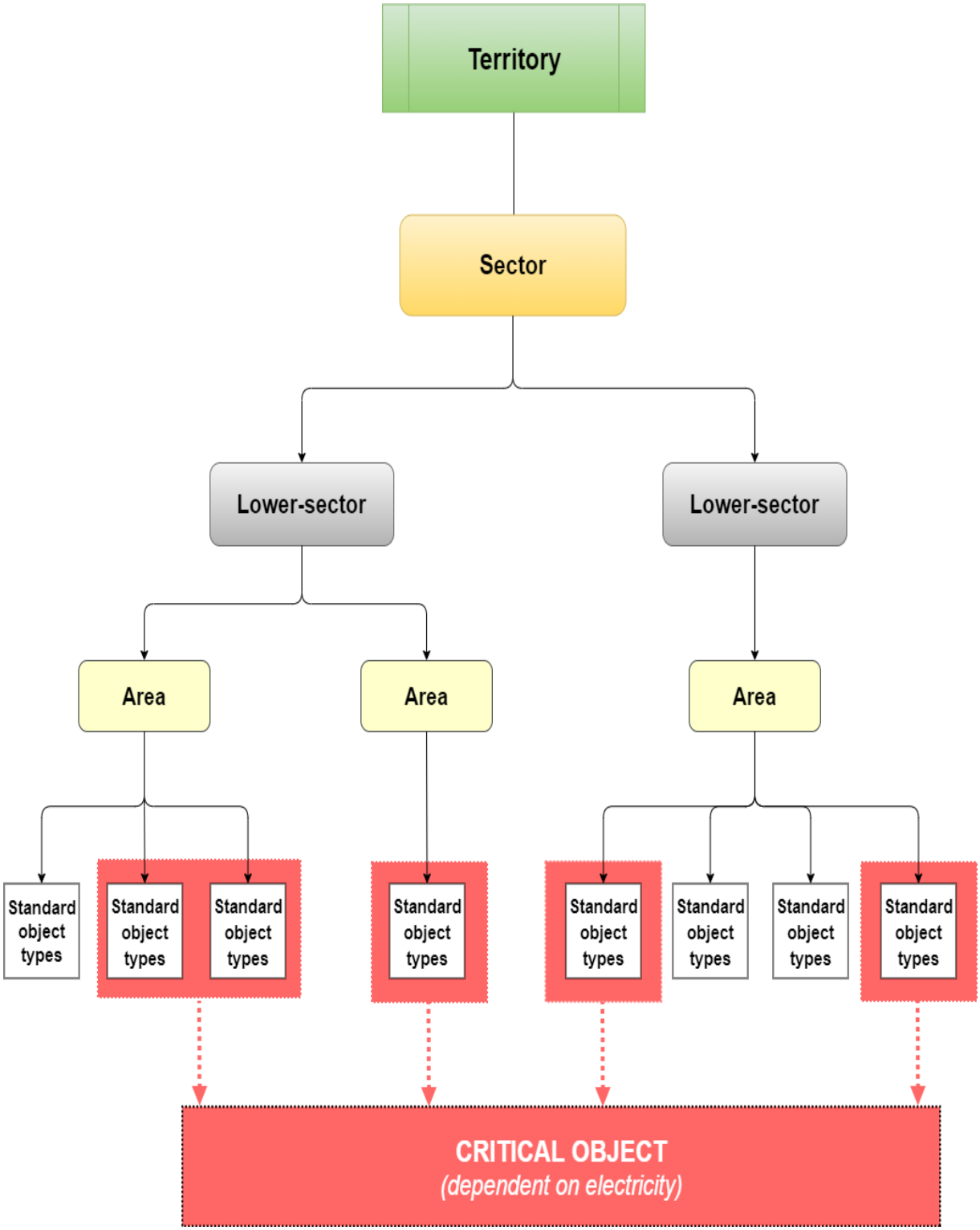

Figure 1 The model for critical objects evaluation - concept
Source: Outcome of the research

The model consists of categories, sectors, lower-sectors, areas, standard object types and individual objects. The category as the top level of the model hierarchy represents processes within the territory that are considered crucial to ensure life-supporting functions and safety of the inhabitants of the region (see Table 1).

Table 1 Catalogue of sectors

ID	Sector
1	Power industry
2	Water management
3	Health care
4	Social services
5	Emergency services
6	Transportation
7	Public administration
8	Waste treatment
9	Education
10	Agriculture and food processing
11	Telecommunication
12	Finance markets

Source: Outcome of the research

The sectors are then decomposed into lower-sectors then to areas and to standard object types. As an example, this decomposition is for energy, water management and health care sectors shown in Table 2.

Table 2 Decomposition of energy, water management and health care sectors (example)

ID	Sector	ID	Lower-sector	Area
1	Power industry	1.1	Electricity	Generation and distribution of electricity
		1.2	Natural gas	Extraction, processing, distribution and storage of natural gas
		1.3	Heat distribution	Generation and distribution of heat
		1.4	Crude oil processing	Extraction, processing, distribution and storage of crude oil
				Operation of gas stations
2	Water management	2.1	Drinking water	Extraction, processing, distribution and storage of drinking water
		2.2	Wastewater treatment	Operation of wastewater treatment

ID	Sector	ID	Lower-sector	Area
3	Health care	3.1	Public healthcare	Operation of ambulatory and urgent hospital services
				Operation of short impatient ward
				Operation of long impatient ward
				Operation of individual ambulatory care
		3.2	Pharmacy services	Operation of pharmacies, which are part of hospitals with impatient care
				Operation of pharmacies, which are part of other hospitals
				Operation of pharmacies with nonstop service
				Operation of other pharmacies

Source: Outcome of the research

The lowest level of the model (standard object types) determines the type of critical objects. From this group, only those objects that are dependent on electricity are selected. The resulted group of standard object types forms up guidance for an evaluator from which the evaluator needs to identify actual objects that are present in the evaluated area. Not all object types necessarily need to have an actual candidate within the region but by having this list the evaluator is guided through the process not to forget important objects.

Table 3 shows an actual decomposition for the water management sector.

Table 3 Water management – critical object decomposition (example)

ID	Standard object types	Lower-sector
1	Water pumping facility Water treatment plant Water tower Facility controlling	Drinking water
2	Water pumping facility Wastewater treatment plant Facility controlling	Wastewater treatment

Source: Outcome of the research

Figure 2 shows the decomposition for the water management sector graphically.

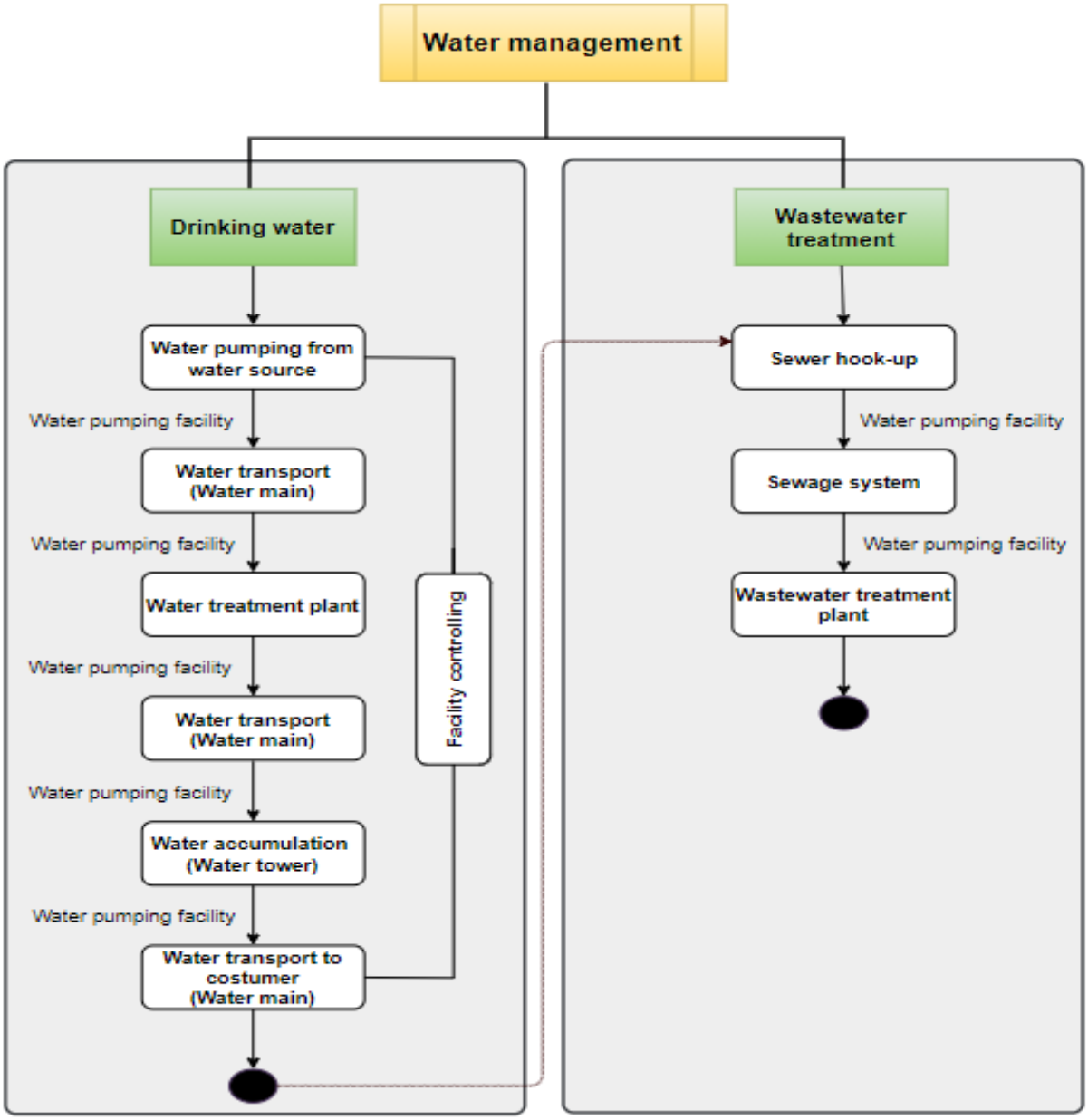

Figure 2 Water management – decomposition (example)[TF1]
Source: Outcome of the research

Summary

The energy sector represents a basic pylon of every prosperous state. Nowadays, electricity stands for a crucial commodity necessary in every human process. A power outage means a critical situation for every territory. There is a strong requirement for standardisation in resilience to critical situations, e.g. mass power outage in a territory. The conducted field research confirmed that by lacking the standardisation the approach how to identify critical objects and how to determine which of those objects need a preferred power supply is very scattered.

Representatives of responsible municipalities and country regions tend to have different approaches to evaluation. The list of identified critical objects within the territory usually vary. This situation causes low resilience of territories to the power outage and a non-uniform approach to recovery. Standardisation in a form of obligatory legislation in this area would greatly improve this situation. The research developed the model which helps responsible representatives to identify critical objects within the evaluated area. This minimizes the risk of omitting important objects, respectively the objects' importance to life-supporting processes in the evaluated area, which he or she might not be aware of their existence. The model builds upon the State Energy Policy of the Czech Republic (Priority V – Energy security) which extends.[1]

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S U M M A R Y

The reliable and secure power supply is the key element on which all human activities and, in many cases, human lives are directly dependent. Excessive long-term power outage (also referred to as a power blackout) is nowadays a real threat to any contemporary modern society, the Czech Republic undoubtedly belongs to. There is the research "Increase of regional resiliency against a power blackout using new technologies and crisis management procedures". This article discusses regional requirements when a power failure occurs. The developed methodology establishes rules for identifying the most important processes and determines the level of importance of the relevant infrastructure (objects) to provide the necessary level of protection of the population and sustainable development in the affected area.

Key words: Municipality, Threat, Power Outage, Resilience, Security of the Territory, Population, Critical Object.

R E S U M É

FRÖHLICH, Tomáš; SLABÝ, Jiří; HON, Zdeněk; NAVRÁTIL, Leoš: HODNOCENÍ BEZPEČNOSTI ÚZEMÍ VE VAZBĚ NA ROZSÁHLÝ VÝPADEK ELEKTRICKÉ ENERGIE

Spolehlivé a bezpečné dodávky elektrické energie představují zásadní předpoklad pro fungování dnešní společnosti, která je často označována jako postindustriální a informační. Na dodávkách této strategické komodity jsou zcela závislé veškeré obory lidské činnosti a v konečném důsledku i samotné lidské životy a jejich zdraví. Z tohoto důvodu představuje rozsáhlý výpadek elektrické energie významnou hrozbu pro každou moderní společnost, mezi které Česká republika jednoznačně patří. Problematikou zajištění nezbytných dodávek elektrické energie při narušení elektrizační soustavy se detailně zabývá výzkumný projekt „Zvýšení odolnosti regionu před hrozbou plošného výpadku elektrické energie s využitím nových technologií a postupů krizového řízení“. Tento příspěvek se věnuje otázkám bezpečnostních potřeb území v kontextu daného ohrožení. Především pak způsobu stanovení důležitých objektů a souvisejících služeb pro zajištění základních potřeby obyvatelstva a funkcí na daném teritoriu.

Klíčová slova: municipality, hrozba výpadku elektrické energie, odolnost, bezpečnost území, obyvatelstvo, bezpečnostně významné objekty.