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DYNAMIC ENERGY ASSESSMENT TOOL FOR THE HOSPITALS

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Research article

Abstract: Electricity represents an essential part of the infrastructures in the whole world. Power outage could be caused as the impact of a natural or anthropogenic disaster, terorism, imbalance between production and consumption and others. The failure also affects infrastructure elements such as hospitals. There is a significant problem if the supply is interrupted in the hospitals. Accessories such as Uninterruptible Power Supply and generators are used for this purpose. Furthermore, it is crucial here to ensure the fuel supply of the units. The aim of this article is to present the possibilities of solving the fuel supply.

Keywords: Dynamic system, Electricity, Hospitals, Assessment tool, Disaster.

Introduction

Humanity has regularly been trying to make life more comfortable. The aim of each person has always been to provide basic life needs. According to Maslow's pyramid of needs, the biological (innate) requirements of each person include the need for breathing, sleep, food, and safety. The provision of these basic needs of humanity varies depending on the evolution of today's world - another way to get warm in prehistoric times when the fire was used. The light provided heat, protection from the competition, the possibility of food preparation, and thanks to the fire; some tools were produced.

Over time, there have been several revolutions that have led to the development of technology and, thus, more comfortable to meet the needs of man. The turning point came in the Middle Ages - a period of classical antiquity when numerous advances in the history of humanity occurred. The supply of drinking water from the water mains was a significant step forward. Vegetables and fruit from the villages began to be supplied to the townspeople. Significant technical progress occurred in the second half of the 18th century, which is referred to as the Industrial Revolution. There was a transition from an agrarian way of life to an industrial way of life. Here, significant technological advances have been recorded, which have led to a simplification of experience and a more comfortable satisfaction of the basic life needs of man.

A valuable source of permanent electric current was discovered in 1800. Subsequently, in the second half of the 19th century, electricity began to enter households. It made the inhabitants' lives more accessible. Over a decade, the role of electrical power plays a vital role in modern day life (Kumar, 2016). Indeed, there is a dependence on the source of electricity. It is used in all areas of human life. Humanity uses power in transport, education, agriculture, and other sectors, where healthcare is undoubtedly also.

Society is traditionally dependent on a whole range of infrastrucutures (Rehak, 2018), where belongs to health care too. To the critical infrastructure belongs different sectors (see Fig. 1), where is health too.

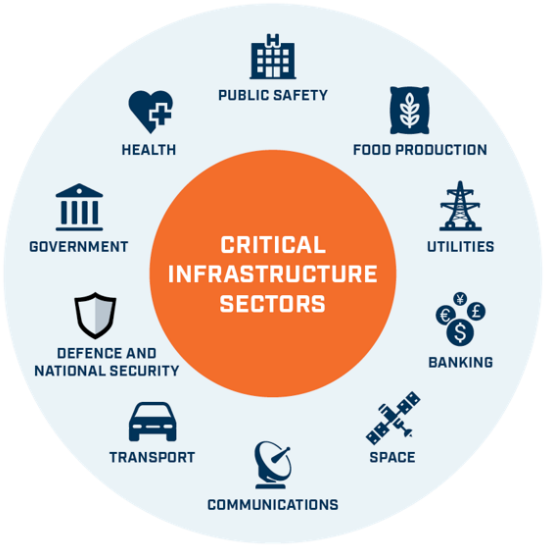

Fig. 1 Critical infrastrucutre sectors (Hutsman, 2019)

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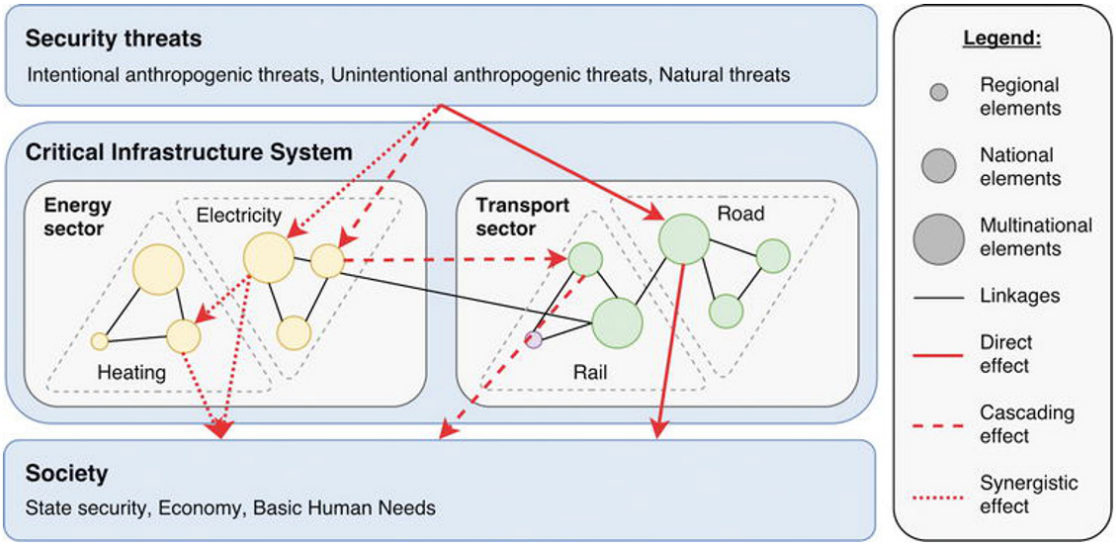

Fig. 2 Cascading effect (Rehak, 2017)

And what does it means cascading effect in the infrastructure? Rehak say that it could be a cascading failure occurs when a disruption in one infrastructure causes the failure of a component in a second infrastructure, which subsequently causes a disruption in the second infrastructure (e.g. an electrical power failure could create disruption in other infrastructure) (see Fig. 2) (Rehak, 2018).

Healthcare is nowadays dependent on electricity sources. It is used in operations, in the intensive care unit, in examinations using modern devices, but also in a routine exam. Several patients are dependent on hospital electricity.

Today, however, there may be situations in which the power supply fails. It may be due to several events, one of which may be natural disasters that cause cascading effects and impact on the lives and health of citizens. Natural disasters are disasters, which is an unpredicted phenomenon that humanity must address (Kumar, 2016). In recent years, climate change and the associated longer and unpredictable occurrence of extreme weather events such as drought, fires, heavy rain, floods, storms, hurricanes, landslides, etc. have more and more affected a lot of countries of the world (Luskova, 2018). Consequences of emergencies and crises lead to direct and indirect threats to lives, health, and the environment in which we occur (Brehovska, 2017).

The impact of disasters is significant for the hospitals. Cascading crises and disasters in the global interconnected system are emerging fields of research in disaster risk reduction (Pescraroli, 2018). Resilience in emergency services has been a top priority, especially for critical or high-value facilities, such as emergency response centers, hospitals, and shelters (Anderson, 2018).

The hospital requirement, therefore, ensures that the supply of critical electrical circuits is not interrupted. Essential electrical circuits include in particular operating theaters, intensive care units, anaesthesiology and resuscitation wards, incubators, and other wards where patients' lives are dependent on electrical power sources. In the event of a power outage, the immediate use of alternative sources of electricity occurs. One of them may be aggregates that could replace power supplies. However, these resources depend on fuel reserves. Most significant hospitals do not have enough fuel to supply critical hospital circuits for more than six hours. Hospital evacuations that occur during, or as a result of, infrastructure outages are complicated and demanding (Vugrin, 2015). Health facilities, especially hospitals, are essential in responding to the disaster situation, including emergency treatment and trauma care (Munasinghe, 2019).

The aim of this paper will be present the current preparedness of the hospitals for the power outage in the Czech Republic and propose the dynamic energy assessment tool.

Power outage in the hospitals, 2019

There are numerous situations, which caused power outage in 2019 in the world. How was mentioned, there is an increasing number of cases, which could have an impact on the power outage. The word power outage is sometimes to use as a power cut, and it means a period when there is no electricity in a building or area (Merian-Webster,

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2019a). The word blackout means a period of darkness (as in a city) caused by a failure of electrical power (Merian-Webster, 2019b).

The outage hit Indonesia on 4 August 2019. More than 20 million inhabitants were affected by the power outage. It affected Jakarta, Java, and other cities primarily. The blackout was affected by the power plant failure. There was affected the hospitals too. Hospitals were dramatically affected by the outages. Relying on generators to power their health services, the result of such a long blackout was the problem of hospital staff prioritizing parts of the hospital that most needed the electricity. There was a reported case where officials from a hospital in West Java were frantically looking for fuel to power their generator (The Monsson Project, 2019). It should be noted here that the electricity distribution in this area is low (see Fig. 3). Thus, a blackout can affect many residents in a moment.

Fig. 3 Electricity in Bali

The next significant blackout was in Argentina, Uruguay, and Paraguay, 16 June 2019. More than 48 million inhabitants were without electric power. Public hospitals and private clinics were running on generators (News 18, 2019). And other patients reliant on medical equipment were encouraged to go to the nearest hospital with a generator (DW, 2019).

The next blackout was in California in 2019. The main problem, which caused a power outage, were wildfires. Pacific Gas & Electric and Southern California Edison began shutting off power to millions of people in a desperate scramble to prevent their transmission lines from sparking wildfires (Los Angeles Times). More than 300 thousand inhabitants were without electric power. The situation was different than in the previous blackouts. In this case, power companies intentionally shut off electrical power because of enormous wildfires.

California Hospital Association leaders said that their operations were largely unaffected by the outages, which began early Wednesday, and some will last five days. Hospitals are required under state and federal law to have backup diesel generators. Those kick in within seconds. As far as they inform, that they have not heard, there has been any significant impact on care (Modern Healthcare, 2019).

In Northern California, Kaiser Permanente's Santa Rosa hospital and two medical office buildings temporarily lost power early Wednesday. It was restored late Thursday afternoon. During that time, elective surgeries were rescheduled, but operations were otherwise normal (Modern Healthcare, 2019).

In Southern California, two of Kaiser's medical office buildings, in Sylmar and Porter Ranch, were closed due to smoke from a nearby wildfire. Appointments were rescheduled (Modern Healthcare, 2019).

And finally, we will mention the hurricane Dorian which affected the Bahamas in September 2019. About 19 thousands of inhabitants were without electric power. The hospitals have emergency plans for preparing for these situations. They also have a generator for energy. In some cases, a hospital will transfer certain patients at very high risk should a power outage occur (CNN, 2019). The utility's power restoration begins with its power plants and power lines that bring electricity to substations, then main lines to police, fire, hospitals, and other critical infrastructure identified by counties. At the same time, FPL starts to restore power to significant roads, grocery stores, pharmacies, and gas stations. Finally, the utility gets to individual neighborhoods and more damaged communities (Energy Central, 2019).

As we can see, power outage (blackout) could be caused by different reasons. One of them could be a technical problem, and on the other hand, it could be by natural disaster. And there are much other reasons for the power outage, which was not this year. As we can read, there is a significant impact on hospitals in the affected area. These hospital requirements are provided by the generators.

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Methodology

In this paper was used four scientific methods. Firstly, it was the analysis, which we used for the study of the hospitals. Secondly, there was used a method comparison, which compares the results from the analysis. Thirdly, the induction method was used, where this method serves the examine the fact of creating a hypothesis from the points obtained. Finally, the heuristic analysis of energy preparedness was used.

The heuristic analysis of the preparedness was developed for the evaluation of the hospitals in the area of energy. Based on this assessment, we will get an accurate idea of the weaknesses and strengths of the assessed hospitals.

Emergency energy supply - this category evaluates the preparedness of the hospitals for emergency energy supplies - the ownership of energy supply replacement units. However, these aggregates are fuel-dependent, and it is, therefore, necessary to assess fuel supply to the hospital. It deals with the area of contractual fuelling, its gas station, etc.

Based on the above analysis, an assessment was performed using the following formula (1):

$$HP = (R + H) / (2 \cdot H) \cdot 100\ \% \qquad (1)$$

where HP is hospital preparedness, R is sum of results (obtained points), H is number of assessed heuristics.

The evaluation methodology consisted in assigning a response to each question answered in the form of valuation from a predefined set of values: -1 = does not agree, 1 = agree, 0 = partly agree, blank field if the problem is not relevant.

Results

Each hospital is prepared for the power outage differently. Some of the hospitals are prepared at a high level, and on the other hand, some are prepared at a low level. This part of the paper will present an evaluation of the three hospitals in the Czech Republic. Each of the hospitals is from a different region. The Czech Republic is divided into 14 regions.

Firstly, we will evaluate hospitals based on the heuristics analysis of energy preparedness. There was an analyzed hospital in the Central Bohemian Region, Hradec Kralove Region and Usti nad Labem Region. Based on this analysis, we take information if the hospital is prepared for the crisis - power outage or not.

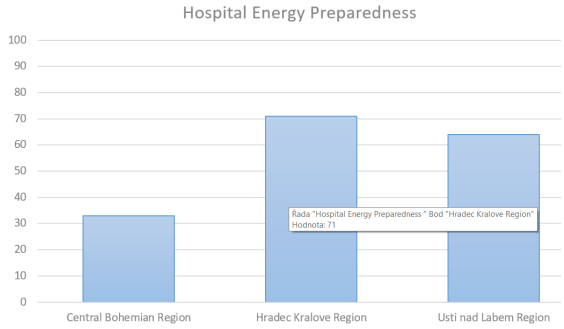

Fig. 4 Hospital energy preparedness

Fig. 4 shows hospital energy preparedness in the Czech Republic. There were three hospitals in different regions. As can be seen, the high evaluation of energy preparedness takes hospital in the Hradec Kralove region. This hospital takes 71 percent of the preparedness. On the other hand, the low level of the hospital preparedness takes hospital in the Central Bohemian region. This hospital takes only 33 percent. And finally, the hospital in the Usti nad Labem region takes 64 percent of the preparedness.

Firstly, we evaluated the hospital in the Central Bohemian region. This hospital takes in the assess 33 percent of the preparedness in the area of emergency energy supply. Consequently, there was obtained information about power sources and stocks.

Tab. 1 Hospital 1

Hospital energy equipment		
Replacement power source	**Consumption**	**Fuel stocks**
UPS		3 hours
Diesel generator I	95 litres per hour	780 litres
Diesel genrator II	42 litres per hour	250 litres

Tab. 1 shows the energy supply of the hospital 1 in the Central Bohemian Region. This hospital has UPS, which has the capacity for three hours. Next, the hospital has two diesel aggregates. First of them will have stock for eight hours if the stock of the barrels will be full. The second diesel aggregate will have stock for 5.5 hours if the stock of the barrels will be complete.

Secondly, we evaluated the hospital in the Hradec Kralove Region. This hospital takes in the assess 71 percent of the preparedness in the area of emergency energy supply. Again, there was obtained information about power sources and stocks.

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Tab. 2 Hospital 2

Hospital energy equipment		
Replacement power source	**Consumption**	**Fuel stocks**
UPS		3 hours
Diesel generator I	32 litres per hour	
Diesel genrator II	32 litres per hour	
Diesel genrator III	32 litres per hour	
Diesel genrator IV	32 litres per hour	
Diesel genrator V	32 litres per hour	
Diesel genrator VI	32 litres per hour	
Diesel genrator VII	32 litres per hour	
Total		8,000 litres

Tab. 2 shows the energy supply of the hospital 2 in the Hradec Kralove region. This hospital has UPS, which has the capacity for three hours. Next, the hospital has seven diesel generators. All of them have an average consumption of 32 liters per hour. Total fuel stocks are 8,000 liters. Stocks for each generators last for 36 hours on average.

Finally, we evaluated the hospital in the Usti nad Labem Region. This hospital takes 64 percent of the preparedness in the area of emergency energy supply. The following table shows the information about the power sources and stocks.

Tab. 3 Hospital 3

Hospital energy equipment		
Replacement power source	**Consumption**	**Fuel stocks**
UPS		3 hours
Diesel generator I	55 litres per hour	300 litres

Tab. 3 shows the energy supply of the hospital 3 in the Usti nad Labem Region. This hospital has UPS, which has the capacity for three hours. Next, the hospital has one diesel generator. The consumption of this diesel aggregate is 55 liters per hour. Total fuel stocks are 300 liters. Stocks are for 5.5 hours.

Based on the comparison of the emergency energy preparedness of the hospitals in the Czech Republic, we can say that the preparedness is at a different level. Some of the hospitals are prepared for 33 percent of the preparedness, and on the other hand, the next hospital is ready for 74 percent of the preparedness. Based on this analysis, we can not say if the hospitals in the Czech Republic are prepared for a power outage or not. However, each hospital must build its interior infrastructure in the area of energy supply.

Discussion

The aim of this paper was to present the current preparedness of the hospitals for the power outage in the Czech Republic and propose the dynamic energy assessment tool.

Electricity represents an essential part of the infrastructures in the whole world. We need power during all of our daily situations. We need electricity, when we would like to go to school or work - underground, at work - we could open the door in times we have not power or our machines or notebooks, children in school using electronic pupil books and of course in the hospital. Electricity in the hospitals is needed for the registration of the patients, for scanning devices as roentgen, during operations, and for monitoring and providing basic life needs. However, the preparedness of the hospitals in the Czech Republic is not at a high level in all hospitals. There is enormous differentiation in the preparedness of the hospitals in various regions.

In this paper, we used the heuristic analysis of preparedness in the area of emergency energy supply. Based on the analysis, we could compare the preparedness of the emergency energy supply in the hospitals. Consequently, we take information about the power sources and stocks in each hospital. There were three hospitals, and each hospital takes a different percent of the preparedness. The other kind of hospital could cause this significant difference - regional, faculty, and others.

And now, is the research question arises. How will be the fuel supply to the generators ensured? How will the supplier or regional office obtain information about fuel shortages? For this purpose, we propose the dynamic energy assessment tool for the hospitals. The aim of this tool will be first to evaluate the preparedness of the hospitals in the region (for this purpose was proposed static assessment tool). Secondly, the information transfer to the dynamic tool, which will be displaying the preparedness of the hospitals in the whole region.

There is an operational and information center in the Czech Republic. This center is at the regional level. Each region has its center and takes information about the emergencies and crisis in their region (see Fig. 5).

Fig. 5 Operation and information center (AV Media, 2019)

Currently is not any of the hospital assessment tools for the monitoring of emergency energy supply. And therefore, we propose a dynamic energy assessment tool for the hospitals. As can be seen, the operational and information center has much information about the current situation in the region. The proposed assessment tool could be a part of this center. Based on the data from the hospitals, they take information about their preparedness. If the system show, that the selected hospital/hospitals are not prepared, operation and information center send data to the distributor or regional office for ensuring the supply of fuel.

The propose of the dynamic energy assessment tool for the hospitals will ilustrate the preparedness of the hospitals. Green H (hospital) shows that the hospital is prepared, and red H indicates that the hospital requires fuel supply. This assessment tool is applicable in all regions in the Czech Republic.

Conclusion

The aim of the paper was to present the current preparedness of the hospitals for the power outage in the Czech Republic and propose the dynamic energy assessment tool. The paper was divided into several parts. Firstly, there was a literature review about the topic of a power outage and the impact on the critical infrastructure. Secondly, there was introduced the power outage in the hospital in 2019. Next, there was presented a methodology, which was used in the paper. The central part of the paper was in the part results. There were analyzed three hospitals and hospital energy equipment. Based on the information, we propose a dynamic energy assessment tool for hospitals. This assessment tool could be a part of the operational and information center in the Czech Republic.

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