Article

Method of Identification and Assessment of Security Needs of a Region against the Threat of a Large Power Outage

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Abstract: The reliable supply of electricity is a key commodity that affects the functioning of today’s society. The long-term disruption of these supplies has far-reaching effects that will have a significant impact on all spheres of our lives. Infrastructure will stop operating and the provided services will be limited or cease. This article focuses on a comprehensive and systematic approach to strengthening the resilience of territorial units in relation to large-scale electricity supply disruption. The main part focuses on the process model of identification and evaluation of key elements of a region that are necessary to ensure the basic needs of its population. The aim of this model is to provide the security management with an effective tool on how to define the security needs in their region and determine specific infrastructure from the security perspective. The model includes a process of determining the priorities of infrastructure in accordance with their importance in the form of a methodological framework. The result is the establishment of a list of safety-relevant objects in the region, which is a necessary prerequisite for the design of an islanded operation and other measures leading to the reduction of impacts caused by large-scale power outages.

Keywords: critical infrastructure; threat; power outage; resilience; population; critical object

1. Introduction

One of the distinctive characteristics of the current state and trend of human society development is high demand for energy consumption, which is especially common in industrially and economically developed countries. None of us can imagine the consequences and impacts of an outage of these commodities on the order of days, weeks or even months without any prediction about their recovery. The dominant and key position within the entire energy sector is occupied by electricity. Today’s post-industrial society is fully and continuously dependent on reliable electricity supplies [1–3]. It can be therefore stated that electricity has become an integral part of our lives, i.e., our society has become absolutely dependent on this commodity. This unique position of electricity clearly declares its inclusion among critical infrastructure across all states of the Euro-Atlantic area [4–8]. Reliable electricity supply is a fundamental building block for other energy sectors and all other critical infrastructure sectors dependent on electricity supplies (e.g., transport, health care, water management, information and communication technologies, etc.) [5,9–11].

The biggest threat in this area is a complete interruption or total outage of electricity supplies on a large scale (blackout). The adjective expressing a large-scale power outage is perceived in two dimensions: the extent of the affected area and the duration of the state without electricity. In the case where such an event occurs immediately, a cascading effect occurs [12,13], consisting of gradual limitation or even complete suspension of supplies of other commodities (e.g., drinking water, natural gas, heat, oil), cessation of production (e.g., chemical or pharmaceutical industry), and non-functionality of all services (e.g., provision of health care, food supply, telecommunication and data connection) [12,14,15].
For this reason, electricity safety and security are a national security priority for every state, especially in terms of ensuring reliable and quality electricity supplies under all conditions, i.e., not only in peacetime, but also during emergencies and crisis situations [16].

Blackout—The Threat of 21 Century

A blackout, or large-scale power outage, can be considered nowadays as one of the greatest security threats. Different definitions of this phenomenon can be found in the literature. From a technical point of view, a blackout is perceived as a time period during which the disturbance of the balance between the production and consumption of electricity occurs, and the reliability of supply of this commodity is threatened as a result [17]. A blackout is a complete power outage in general [18]. According to Commission Regulation (EU) 2017/1485, which establishes a guideline for the operation of electricity transmission systems, a blackout is perceived as meeting at least one of the following conditions: more than 50% of consumption has been lost in the region affected by a power outage, or voltage has been lost for at least 3 min, which then triggers recovery plans. The risk of blackout increases in the event of technical failures; natural events, cyber-attacks, human failure during maintenance work, or a combination of these factors [14].

The nature of the danger which this threat represents is given primarily by the seriousness of its impacts, which leads to a cascading and fundamental disruption of all economic and social spheres in society [14]. A specific feature is that these adverse effects develop over time without electricity at a very dynamic pace. They deepen and can cause irreversible and even fatal damage. The unique position of this threat arises because electricity is a key and essential commodity for meeting all of humanity’s needs [5]. Today’s modern society is a consumer of electricity at literally every step and moment during the performance of both work and leisure activities. Nevertheless, a significant part of the population perceives this commodity as a completely normal and automatic part of their lives, without acknowledging the possibility of a long-term outage. However, looking back to past years clearly shows the exact opposite [19,20]. The blackout caused in Auckland, New Zealand in 1998 can be stated as an example. This event can be considered one of the longest in history in terms of its duration. The affected region was without electricity for five weeks [21,22]. Another example is the breakdown of the electricity grid that occurred in India in 2012 [12]. More than 620 million people were left without electricity [23–25], which represents a twelfth of the world’s population. Dozens of similar cases, although smaller in size, can be found in the last two decades. All developed countries strive to not only prevent these crisis situations (which is not always possible), but to establish measures that will reduce the negative impact of these crisis situations on our lives.

The islanded operation system is included among effective measures to minimise the effects of a blackout [26–28]. Islanded operation represents the separation of a part of the electricity system that operates independently of the whole system [29]. The purpose of this measure is the creation of a sufficiently functional electricity grid using local sources of electricity located in the affected region or territory or in its surroundings. This will ensure the functionality of the region until the entire electricity system can be restored. The availability and technical readiness of all involved components and entities are the main decisive factors for the implementation of the islanded operation. In crisis situations, a supply of electricity is provided to selected consumers in a limited manner as a result. This method of supply is not intended to provide full electricity supply to the affected region but rather to maintain the minimum operational functionality of the most important elements of the region that provide basic needs for its population [30,31]. From a technical perspective, this measure does not represent a significant innovation to the current professional society. The weakness of this measure lies in the level of planned process preparation of the region, particularly in determining the preferences of individual elements on the part of end consumers. The problem lies in the systematic and objective definition of key consumption points (so-called safety-relevant objects) that will be included in the islanded operation. This article focuses precisely on the issue of territorial assessment, with the aim of defining
safety-relevant objects intended for the priority supply of electricity in the event of a disruption, including the determination of their priority order.

2. Territorial Security Assessment Model

2.1. Starting Point

Modern society is fully reliant on the faultless functioning of individual elements of the infrastructure, which ensures the satisfaction of a population’s needs. Some of these infrastructures are even classified as critical. However, the concept of critical infrastructure is clearly conceived by a centralist approach from the point of view of the state or the European Union. The position and needs of a lower territorial unit are neglected as a result of this approach. These units may be regions or even municipalities. It should be realised that, even at these levels, the infrastructure, which is specific to a given region, may be present, and it is indispensable and absolutely essential in overcoming the impacts of crisis situations. However, its composition may not necessarily be equivalent to the concept of national or transnational critical infrastructure. The different needs and related priorities of the region and its inhabitants are the reason for this dual view. As an example of this disparate perception, medical facilities with limited number of acute beds (e.g., up to 200) which do not have an established emergency room, can be illustratively stated. Such facilities are not an element of critical infrastructure from the general point of view of the state in the field of healthcare, because their capacity is relatively insignificant and their facilities can be relatively easy to replace. However, from the perspective of the region or municipality in which this facility is located, it is an infrastructure that is completely necessary for the corresponding territory and its population.

The following process model was proposed to methodically and unambiguously define the fundamental needs of a specific region regarding the threat of a large-scale power outage. The purpose of this model is to objectively evaluate and define specific areas and their infrastructural representation, which are crucial for ensuring the security in the region, including the setting of their priorities in accordance with their social status and importance. The mentioned concept of security needs is based on Maslow’s pyramid where ensuring the safety and security represents the second most important level of human needs. At the same time, their fulfilment automatically assumes the satisfaction of the first or initial level of human needs, namely the provision of physiological needs [32]. The whole model can be methodically divided into the identification and evaluation of safety-relevant objects in the region.

2.2. Identification of Safety-Relevant Objects in the Region

In order to identify the safety-relevant objects in a region, the processes and activities that these objects provide must be known and assessed. The advantage of this method is primarily in its maximum objectivity, complexity, and above all, the capacity to identify relevant links and contexts. The provision of a supply of drinking water serves as a demonstrative example of this process approach. The water treatment plant is one of the crucial facilities for ensuring the supply of drinking water to the final consumer. In this facility, raw water that is drawn directly from the water source is then converted into drinking water. However, the operation of this facility alone will not guarantee the availability of drinking water. The operation of other facilities involved in its supply, such as pumping stations, reservoirs, etc., must be secured along with the water treatment plant. Only by ensuring that all the essential facilities within the water supply process are operational will drinking water of the necessary quality be delivered to the final consumer. This example demonstrates the necessity of thorough process knowledge of the entire area. With this knowledge, it is possible to specify the actual security needs and subsequently identify the safety-relevant objects in the region. For this reason, a process approach was chosen for the presented model for assessing the security needs of the region [16].
Sector Category Catalogue

The fundamental part of the whole model is a sector category catalogue (see Figure 1) that reflects the socio-economic fields of human activity. These fields are directly related to ensuring the basic needs of the population and the corresponding functions of the region designated to them, in direct relation to the disruption of electricity supplies. The resulting catalogue defines the sectors that play a significant role in ensuring the basic conditions for the proper and safe life of all the residents and visitors in the evaluated region.

![Sector category catalogue](image)

Figure 1. Sector category catalogue [33].

Following this catalogue, the individual sectors are distributed according to their nature and focus on industry-related subsectors (see Table 1). Each of these subsectors is represented by a specific area consisting of the type of elements needed for its operation. Within the set of these identified type elements, only those dependent on the supply of electricity, in terms of ensuring their operation and functioning, are considered. From the point of view of the threat of electricity supply disruption, these elements represent typical priority consumption points or so-called typical safety-relevant objects of the region.
<table>
<thead>
<tr>
<th>Sector</th>
<th>Subsector</th>
<th>Field</th>
<th>Type Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy industry</td>
<td>Electricity</td>
<td>Ensuring production, transmission and distribution of electricity</td>
<td>Production plants, Substations, Transformer stations, Elements of protection and control system, Technical control rooms</td>
</tr>
<tr>
<td>Natural gas</td>
<td></td>
<td>Ensuring production, transportation, distribution and storage of natural gas</td>
<td>Border transfer stations, Compression stations, Technical control rooms, Transfer stations, Control stations, Gas storages, Gas closures, Control and security systems, Related technological objects</td>
</tr>
<tr>
<td>Heat</td>
<td></td>
<td>Ensuring production and distribution of thermal energy</td>
<td>Heat plants (power plants, heating plants, boilers), Technical control rooms, Transfer stations, Thermal distribution equipment, Control and security systems, Related technological objects</td>
</tr>
<tr>
<td>Petroleum and petroleum products</td>
<td></td>
<td>Ensuring production, transportation, distribution and storage of petroleum and petroleum products</td>
<td>Refineries, Technical control rooms, Buildings of major operators (warehouses, tank farms, pumping stations, storage tanks, etc.), Oil pipelines, Product pipeline</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Public fuel stations and non-public fuel stations (e.g., for transport operators, Emergency units, etc.)</td>
</tr>
<tr>
<td>Water management</td>
<td>Drinking water</td>
<td>Ensuring supply of drinking water</td>
<td>Distribution and pumping stations, Handling units, Water treatment plants, Reservoirs, Technical control rooms and other facilities of water infrastructure operators</td>
</tr>
<tr>
<td>Wastewater</td>
<td></td>
<td>Ensuring wastewater treatment</td>
<td>Distribution and pumping stations, Sewage treatment plants, Technical control rooms and other related infrastructure</td>
</tr>
<tr>
<td>Healthcare</td>
<td>Providing healthcare</td>
<td>Provision of outpatient, one-day and acute inpatient care</td>
<td>University and large regional hospitals, Highly specialized medical facilities, Regional hospitals with complex care, Regional hospitals, Narrow-focus medical facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provision of follow-up inpatient care</td>
<td>Aftercare hospitals, Hospitals for the long-term sick, Hospitals for treatment of tuberculosis and respiratory disorders in adults and/or children, Psychiatric hospitals, Rehabilitation institutes, Other specialized medical institutions, Other specialized medical institutions for children, Sanatoriums for children, Hospices, Other inpatient facilities</td>
</tr>
<tr>
<td>Sector</td>
<td>Subsector</td>
<td>Field</td>
<td>Type Elements</td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>-------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Providing long-term inpatient care</td>
<td>Aftercare hospitals, Hospitals for the long-term sick, Hospitals for treatment of tuberculosis and respiratory disorders in adults and/or children, Psychiatric hospitals, Rehabilitation institutes, Other specialized medical institutions, Other specialized medical institutions for children, Sanatoriums for children, Hospices, Other inpatient facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provision of (independent) outpatient care</td>
<td>Polyclinics, Clinics, General practitioners, Dentists, Other specialists</td>
</tr>
<tr>
<td></td>
<td>Pharmacy care</td>
<td>Ensuring operation of pharmacies that are part of hospitals providing acute care</td>
<td>Institutional pharmacies which are part of hospitals providing acute care</td>
</tr>
<tr>
<td></td>
<td>Pharmacy care</td>
<td>Ensuring operation of pharmacies that are part of other hospitals</td>
<td>Institutional pharmacies which are part of other hospitals</td>
</tr>
<tr>
<td></td>
<td>Pharmacy care</td>
<td>Ensuring operation of pharmacies with non-stop operation</td>
<td>Non-stop pharmacies</td>
</tr>
<tr>
<td></td>
<td>Pharmacy care</td>
<td>Ensuring operation of other pharmacies that are not part of hospitals</td>
<td>Public (other) pharmacies which are not part of hospitals</td>
</tr>
</tbody>
</table>
The set of type elements is a useful and illustrative tool for each area. Based on its information, the orientation toward identifying specific infrastructural elements is facilitated in the evaluated region. It is necessary to ensure a priority supply of electricity for the selected objects in the event of crisis situations in the power industry.

2.3. Evaluation of Safety-Relevant Objects in the Region

The set of safety-relevant objects for the assessed region can be obtained based on the identification process of the type elements. All the objects included in this set are evaluated as equivalent. However, this principle of parity is insufficient in terms of satisfying the basic needs of the population in the event of blackout. The main shortcomings of this principle include the fact that the interdependencies between individual objects are not respected. This is best illustrated by the lack of social preferences of individual needs perception in relation to preserving the integrity of the individual during the immediate threat to their life or health. The necessity to secure the needs of an individual generally develops over time depending on how the crisis situation develops and how well the society is able to deal with its effects. Due to these factors, the method of evaluation of the set of safety-relevant objects that aims to establish a clear ranking of their importance in ensuring the basic needs of the population and associated functions of the region is a crucial component of the proposed model. Given that it is always necessary to carefully consider a number of factors at once when evaluating safety and security, an approach based on the multicriteria decision-making method was selected. It is an operational research technique that is applied when choosing between several options. These options or variants are presented in the form of evaluation criteria. The various evaluation criteria each represent varying levels of importance. An example of varying importance can be seen in the healthcare sector. Even though the evaluated region may have a number of medical facilities, not all of them are equally crucial in terms of providing healthcare. Some provide only outpatient care, some emergency care, some acute inpatient care, some only aftercare, etc. This example demonstrates the need for rules to be established for the prioritisation of these objects. This difference is expressed through a weighting factor [34]. The subjects of the evaluation within this model are individual safety-relevant objects. The outcome is the determination of their priority order for securing the safety and security of the region in relation to a specific threat [16]. The priority order is determined on the basis of the index which individual objects obtain within the evaluation process. The resulting interpretation is based on the concept of the maximisation criterion by which an object with a higher index value also gains a higher priority in the overall order of the set. The entire process of evaluating the safety-relevant objects is designed as a two-level process.

2.3.1. First Level of Evaluation

The purpose of the first level of evaluation is to determine the basic categories of importance for all safety-relevant objects of the evaluated region. These categories represent the individual priorities of these objects in terms of providing the basic needs of the population and related functions in the given region.

Evaluation Criteria

The whole evaluation process consists of the following five criteria. Within each criterion, group types are defined, which the evaluated object can represent according to its purpose. An object can always represent only one group type. For purposes of quantification and subsequent comparison, the individual group types within each criterion were evaluated numerically using the so-called value coefficient (Vc). This coefficient is expressed in the numerical range [1.0, 4.0]

Criterion 1: Impact on the Lives and Health of the Population

This criterion assesses the object in terms of possible impacts on the lives and health of the population in the evaluated region (see Table 2).
Table 2. Scales of the impact criteria on the lives and health of the population.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>Group Type Description</th>
<th>$V_C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of primary impact on the lives and health of the population</td>
<td>The dysfunction of this area has a direct impact on the lives and health of the inhabitants of the evaluated region due to the large-scale electricity supply disruption. As a result of immediate or short-term (in the order of hours) outages or restrictions of the provided services within this region, there may be an immediate threat to the life and health of the population.</td>
<td>3.0</td>
</tr>
<tr>
<td>Area of secondary impact on the lives and health of the population</td>
<td>The dysfunction of this area has an indirect impact on the lives and health of the inhabitants of the evaluated region due to the large-scale electricity supply disruption. As a result of prolonged (in the order of tens of hours to days) outages or restrictions of provided services within this region, there may be a mediated threat to the life and health of the population.</td>
<td>2.0</td>
</tr>
<tr>
<td>Area without impact on the lives and health of the population</td>
<td>The dysfunction of this area has no direct or indirect impact on the lives and health of the inhabitants of the evaluated region due to the large-scale electricity supply disruption. Therefore, the outages or restriction of services provided in this area do not pose any potential danger the life and health of the population.</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Criterion 2: Service Preferences

This criterion assesses the object from the point of view of the preferred services provided to the population in the evaluated region (see Table 3).

Table 3. Scales of the service preference criteria.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>Group Type Description</th>
<th>$V_C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area related to the living needs of the population</td>
<td>The basic living or subsistence services are provided to the population within this area. These are services that provide the physiological needs necessary to maintain the life and health of the population.</td>
<td>4.0</td>
</tr>
<tr>
<td>Area related to the support of the living needs of the population</td>
<td>Services that are directly related to providing the living needs of the population are provided within this area. The living needs of the population would be provided only temporarily and to a very limited extent without the functioning of these services.</td>
<td>3.0</td>
</tr>
<tr>
<td>Area related to the security needs of the population</td>
<td>Services that are directly related to ensuring the protection and safety of the population are provided within this area. The subject of these services is to ensure the protection and safety of life and health of the population, including their property.</td>
<td>2.0</td>
</tr>
<tr>
<td>Area of other services for the population</td>
<td>Services that do not fall into, or cannot be included in, the types of groups within this criterion are provided to the population within this area. These are the so-called other services that are not related to providing the living needs and security of the population.</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Criterion 3: Security Profile of the Provided Services

This criterion assesses the object from the point of view of security and social status in relation to the emergency situation in the evaluated region (see Table 4).

Criterion 4: Time Dependent Loss of Service

This criterion assesses the object from the point of view of time dependent loss of the provided service, leading to its immediate or gradual loss or its restriction in the evaluated region (see Table 5).
Table 4. Scales of the security and social profile criteria.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>Group Type Description</th>
<th>V_c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area involved in resolving the security situation</td>
<td>Area of services that are directly involved in the tactical, operational and strategic management of the security situation (emergency or crisis situation).</td>
<td>3.0</td>
</tr>
<tr>
<td>Area requiring assistance for the continuity of services</td>
<td>Area of services where continuity must be secured in case of the security situation (emergency or crisis situation). These services are directly related to the immediate threat to the life and health of the population.</td>
<td>2.0</td>
</tr>
<tr>
<td>Area of other services</td>
<td>Area of services that do not fall into, or cannot be included in, the group types within this criterion. These are the so-called other services that are not included in resolving the security situation and do not require assistance for ensuring the continuity of the operations related to the immediate threat to life and health of the population.</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 5. Scale of the time dependent loss of service criteria.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>Group Type Description</th>
<th>V_c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area with immediate loss of service and its functionality</td>
<td>There will be an immediate loss of service and its functionality in this area from a time perspective. This type of service becomes immediately unavailable.</td>
<td>3.0</td>
</tr>
<tr>
<td>Area with gradual loss of service and its functionality</td>
<td>There will be a gradual loss of service and its functionality in this area from a time perspective. This type of service will be available in a maximum of 8 h after the power outage.</td>
<td>2.0</td>
</tr>
<tr>
<td>Area with partial limitation of service and its functionality</td>
<td>There will be a partial loss of service and its functionality in this area from a time perspective. This type of service will still be available to a limited extent after the power outage.</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Note: This criterion does not consider the possible existence of alternative sources of electricity as it is only an individual solution, and not a system solution, for the protection of the whole process.

2.3.2. Weighting Coefficients

The importance of the individual evaluation criteria is not and cannot be seen as identical, as mentioned above. Therefore, the weights are assigned to the evaluation criteria, which express the importance of each criterion. The weights define how important the criterion is in relation to the other criteria. These weights are expressed numerically in the interval [0.17, 0.34], and their total sum is equal to one. As the numerical value of the weight increases, the importance of the criterion increases, and vice versa. The weight is referred to as the weighting coefficient (Wc) within this model. The weighting coefficients of the individual evaluation criteria used in the presented model are shown in Table 6. The determination of the weighting coefficients was performed using the scoring method from [34].

Table 6. Weighting coefficients of the evaluation criteria.

<table>
<thead>
<tr>
<th>Designation of the Evaluation Criterion</th>
<th>Wc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion 1: Impact on the lives and health of the population</td>
<td>0.34</td>
</tr>
<tr>
<td>Criterion 2: Service preferences</td>
<td>0.28</td>
</tr>
<tr>
<td>Criterion 3: Security profile of the provided services</td>
<td>0.21</td>
</tr>
<tr>
<td>Criterion 4: Time dependent loss of service</td>
<td>0.17</td>
</tr>
</tbody>
</table>

2.3.3. Priority Determination

The result of the evaluation process is the determination of the priority order of all evaluated objects. This prioritisation is determined by the basic priority safety-relevant object index [BP SROB index]. Each evaluated object has a unique value of this index.

The value of the BP SROB index is obtained by the sum of the products of the value coefficients of individual criteria that the evaluated object acquires and the relevant weight-
The evaluation of each group type in the criterion is therefore multiplied by the weight assigned to that criterion. Subsequently, all these multiples are added.

The whole evaluation process consists of two phases. In the first phase, all the identified safety-relevant objects are evaluated only on the basis of evaluation criteria 1–4. The result of this process is a basic categorization of these objects into priority groups, but without the attribute of their interdependencies. The mathematical notation for this calculation is expressed by the following formula:

\[
\text{Index}_{(SROB)} = (V_{C1} \times W_{C1}) + (V_{C2} \times W_{C2}) + (V_{C3} \times W_{C3}) + (V_{C4} \times W_{C4}) \tag{1}
\]

or

\[
\text{Index}_{(SROB)} = \sum_{i=1}^{n} (V_{Ci} \times W_{Ci}) \tag{2}
\]

Legend:
Index_{(BP SROB)}: Basic priority of the safety-relevant object index

\[V_{Ci} \]: Value coefficient criterion
\[W_{Ci} \]: Weighting coefficient criterion

Based on the performed evaluation, it is possible to sort the individual objects according to the value of the BP SROB index. For the final interpretation, a scale of priority groups is set. This scale reflects the limits that the values of the evaluated objects can reach. The range of these limits is directly dependent on the Value and Weighting coefficients. The maximum (upper) value for this limit is obtained after reaching the highest values of the given calculation formula. On the contrary, gaining the lowest value defines the minimum (lower) limit. The principle of the so-called Pareto rule \([35]\) was used to define the groups with the highest priority (with the exception of low priority). It is a respected analytical technique used in managerial decision-making processes. This technique is based on the assumption that 20% of the causes cause 80% of the result. This principle was chosen in order to give the highest priority to the truly necessary objects only. The scale of the resulting priority groups is presented in Table 7.

<table>
<thead>
<tr>
<th>Description</th>
<th>Index Value</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high priority in terms of ensuring the security needs of the region, i.e., ensuring the basic needs of the population and maintaining the necessary continuity of the functions of the region.</td>
<td>3.28–2.62</td>
<td>1</td>
</tr>
<tr>
<td>High priority in terms of ensuring the security needs of the region, i.e., ensuring the basic needs of the population and maintaining the necessary continuity of the functions of the region.</td>
<td>2.61–2.09</td>
<td>2</td>
</tr>
<tr>
<td>Medium priority in terms of ensuring the security needs of the region, i.e., ensuring the basic needs of the population and maintaining the necessary continuity of the functions of the region.</td>
<td>2.08–1.66</td>
<td>3</td>
</tr>
<tr>
<td>Low priority in terms of ensuring the security needs of the region, i.e., ensuring the basic needs of the population and maintaining the necessary continuity of the functions of the region.</td>
<td>1.65–1.00</td>
<td>4</td>
</tr>
</tbody>
</table>

2.3.4. Second Level of Evaluation

The subject of the second level is the evaluation of interdependencies and links between objects. The aspect of the object dependence is included in the second phase of the evaluation process (criterion 5). However, it is recommended that this evaluation be performed only for objects that received the highest priority in the first level of evaluation, i.e., very high priority. The factor of usability and feasibility is one of the main reasons for the decision to evaluate only the safety-relevant objects having the highest priority in terms of the critical dependence criterion. The first reason for this decision is that there are usually a large number of identified safety-relevant objects in the region. However, the real possibilities and capabilities of ensuring operation in the event of a major power outage are always limited. As a result, the needs of the objects with the highest priority are
expected to be met most quickly. Therefore, the evaluation of interdependencies within the corresponding criterion focuses only on the most important group of objects. The second key reason is feasibility, which is also a purely practical reason in this case. The idea of evaluating the interdependencies and connections of all identified safety-relevant objects in the region represents a very demanding task (in terms of human resources, necessary knowledge and time capacity), which would not be dealt with in real conditions. Moreover, it can be stated that the effort made in such a case would never be lower than, and would at least be directly proportional to, the resulting effect. This would clearly reject the basic principle of optimizing the costs incurred for planned protection measures in relation to their effectiveness and benefits [36].

Evaluation Criterion

The second level of evaluation is performed through only one criterion, which is labelled as Criterion No. 5: Critical dependence. This criterion assesses the object in terms of dependence on the supply of products, works or services necessary to ensure its functionality and operation (see Table 8).

### Table 8. Scale of the critical dependence criteria.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>Group Type Description</th>
<th>Vc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existential dependence</td>
<td>This dependence represents the supply of products, works or services whose interruption will result in the immediate cessation of the activities of the primary object. The primary object becomes non-functional, meaning it cannot fulfil its purpose as a result of this interruption. The primary object and the provision of its services is therefore existentially dependent on this supply.</td>
<td>2.0</td>
</tr>
<tr>
<td>Significant dependence</td>
<td>This dependence represents the supply of products, works or services whose interruption will result in the gradual reduction or even cessation of the activities of the primary object. A complete cessation occurs no later than 8 h after the interruption of the supply. The primary object remains temporarily functional, meaning it still can fulfil its purpose as a result of this interruption. The primary object and the provision of its services are therefore significantly dependent on this supply, but the consequence of the outage will manifest itself with a time delay (i.e., after 8 h).</td>
<td>1.0</td>
</tr>
<tr>
<td>Other dependence</td>
<td>This dependence represents the supply of products, works or services whose interruption will result in an immediate or gradual reduction or even cessation of the activities of the primary object. The primary object remains functional, meaning it can fulfil its purpose, but only to a limited extent as a result of this interruption. Alternatively, this supply is replaceable. The primary object and the provision of its services are therefore secondarily dependent on this supply and can function without it.</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Determining the Interdependencies and Links

The purpose of this evaluation phase is to identify the interdependencies and links that determine the operation and function of objects with the highest priority. In practice, it often happens that, as a result of a detailed mapping of these interdependencies, other objects will be revealed. It will become necessary to assign a higher priority to these objects than they were assigned in the first level of evaluation. The basic priority of the safety-relevant object index that provides the identified dependence is then adjusted according to the type of dependence in relation to the object with the highest priority. As a result of this fact, there may be a shift, such as an increase in the overall basic priority of the object providing this critical dependence (e.g., supply of an external product, work or service). In addition, this fact is also influenced by the frequency of the occurrence of this object providing the dependence in more objects with the highest priority. As a result, the final value of this index may be greater than the specified upper limit of the calculation model (see Table 7). However, the newly rated object will remain included in this highest group. The achieved value of the index only modifies its internal order. A detailed and accurate
idea for prioritising the group of top-priority safety-relevant objects is obtained as a result. The mathematical notation for this calculation is expressed using the following formula:

\[
\text{Index}_{(EP\ SROB)} = \text{Index}_{(BP\ SROB)} + V_{C5}
\]  

(3)

Legend:

\(\text{Index}_{(EP\ SROB)}\): End priority of the safety-relevant object index

\(\text{Index}_{(BP\ SROB)}\): Basic priority of the safety-relevant object index

\(V_{C5}\): Value coefficient of the Criterion No. 5: Critical dependence

3. Methodological Procedure of Territorial Security Assessment

The proposed methodological procedure contains a brief and organized description of activities leading to the identification and subsequent assessment of the security needs and their provision in the region, which address the threat of large-scale electricity supply disruption (see Figure 2). These needs represent the process of ensuring the basic conditions for the life and health of the population and the related key functions of the region. Meeting these needs significantly strengthens the overall resilience of the region, and above all, helps overcome the negative impacts of the addressed crisis. The goal is the reduction of fatal damage while maintaining sustainable development of the affected region and its society. The result of this procedure is the establishment of a list of safety-relevant objects whose purpose is to satisfy these needs. Part of this list is also the determination of the priority order of these objects. The knowledge of the safety-relevant objects is a basic element of the evaluated region in terms of preparation for overcoming critical situations in the power industry. At the same time, it is necessary input information for planning the islanded operation, which is one of the most effective measures in overcoming the consequences of a blackout. This process can be summarized in the following steps.

Figure 2. Methodological procedure of territorial security assessment.
Step I: Selection of the evaluated region

The region which will be evaluated in terms of safety needs will be defined by the user in the initial step. The term ‘region’ is defined by a determined technical unit which creates a common framework of relations combining material and social reality [37]. In practice, this unit can be a territory, region or municipality.

Step II: Definition of the sector categories

The sectors considered important in terms of securing the needs of the population and related functions of the region are subsequently defined for the selected region. These sectors are divided into the subsectors and areas of human activity that they provide according to their focus. Each significant area contains indicative infrastructural representation in the form of type objects, which ensure the operation of these areas. The output of this step is creating a catalogue of sector categories which will provide the user with a guide on how to orientate within the given issues and which areas to focus on primarily. From this catalogue, the user selects only those sectors which occur in the evaluated region and which they consider necessary. They may also be able to add specific sectors not included in this catalogue.

Step III: Object identification

Based on the defined sector categories, specific objects that represent the individual categories are subsequently identified in the selected region. The so-called type elements represent support and a useful guide for the identification of these objects. These predictively determine which objects are in the given sector, subsector and area, and on which the user should focus. As a result, the user is greatly facilitated in the entire identification process, which is characterised by its multidisciplinary scope. The database of the type elements is an integral part of the input catalogue of sector categories.

Step IV: Evaluation process

(a) First level of evaluation

Each identified object in the region is evaluated through the following criteria in order to determine the basic priorities of the object:

- Criterion 1: Impact on the lives and health of the population.
- Criterion 2: Service preferences.
- Criterion 3: Security profile of the service provided.
- Criterion 4: Time-dependent loss of service.

The result of the evaluation process is the division of these objects into priority groups according to their importance, in terms of ensuring the basic needs of the population and related functions of the region in relation to a large-scale power outage. This division is determined by the achieved value of the Basic priority of the safety-relevant object index. This is the first level of the evaluation process.

(b) Second level of evaluation

For objects with the highest priority, their dependencies on the external deliveries of products, works or services necessary to ensure their operation and functionality are subsequently evaluated. This evaluation is expressed through the following criterion, which distinguishes three types of dependencies: existential, significant and other. This is the second level of the evaluation process.

- Criterion 5: Critical dependence.

The end priority index of the safety-relevant object that provides the identified dependencies is then adjusted according to the type of dependence in relation to the object with the highest priority. This can result in a change in the priority group of this dependent object. The reason for this change may be the fact that this object provides such subcontracts without which the primary object cannot function fully and is therefore fully dependent on it.
Step V: Establishment of a prioritised list of the safety-relevant objects of the region

The output of the entire process of assessing the security requirements of the region is the determination of a prioritised list of safety-relevant objects for the selected region. The user thus obtains not only a simple list of all the important objects in relation to ensuring the basic needs of the population and the functions of the region designated to this purpose in the context of the given threat, but this list is also arranged according to priorities of social importance.

4. Discussion

The described model and the related methodological procedure provide a comprehensive and systematic solution for determining the fundamental set of requisite needs in the region for addressing the danger of large-scale power outages. By defining the infrastructure of these needs in the form of so-called safety-relevant objects, the needs are then prioritized with regards to maintaining the individual's integrity in real time. The end users of this methodology are representatives of the region whose competences include crisis management and the protection of the population against security threats, both natural and anthropogenic in nature. The target group of end users is based on the fact that these security managers have appropriate knowledge and competencies in their given field. The output processed by these managers is in the form of an organised list of safety-relevant objects, which then provides a framework for energy companies. In the event of a crisis situation with the islanded operation or other similar measures being established in the region, these companies will manage the flow of available electrical power according to the set priorities. The importance of the presented methodology thus significantly benefits the multidisciplinary cooperation, which is nowadays a very important aspect in terms of sustainable development of each territorial unit in overcoming non-standard situations.

In accordance with the proposed model, it is possible to argue, to some extent, about its complexity, which requires perfect knowledge not only of the evaluated region but also of individual sectors. However, this fact fully reflects the complexity of the threat of power outage, especially the wide range of consequences that its occurrence causes. Therefore, an effective defence against these consequences also cannot be completely trivial. This is especially the case with regard to the dependence of the production sphere on the supply of electricity, which differs significantly from other media, as it is not yet storable in large quantities in the form of emergency stocks. The determined parameters of the computational part of the model may also raise certain doubts. The presented model was created as a result of a research task, and its setting reflects the knowledge of the research team gained in the national environment of its development. However, the whole model is built as an open process, which allows the modification of individual parameters in accordance with different perceptions of security-political preferences, technical dispositions and other specifics of individual locations where it would be applied.

In addition to its primary use in the setup of an islanded operation, this model can also be used in the process of resuming the supply of electrical power from the public network after a major blackout. It is necessary to consider that these supplies will be restored gradually during the resumption of electricity supplies. It cannot be assumed that all of the end consumers will be supplied at the same time. This process is gradual and usually takes several hours or days. This recovery period is influenced by a number of factors: availability of electricity in correspondence with the gradual start of its production, the size of the affected region and the complexity of the transit apparatus, technical dispatching capabilities, etc. Therefore, it is necessary to prioritise the electricity supply, even in these cases, to the most important infrastructure, whose identification and prioritisation is provided by the presented model.

5. Conclusions

The presented model represents a comprehensive process approach on how to determine which object or infrastructure is important in a given region, in terms of the restoration
of electricity supply and subsequently with what priority. According to this prioritisation, it is then possible to design an islanded operation or even the actual process of restoring the supply of electricity from the network. A certain parallel can be seen in the concept of critical infrastructure. Unfortunately, this concept is aimed only at the level of an entire state or the European Union, where specific and important needs of a regional or local nature are completely overlooked.

In a broader sense, the principle of this model is inspiring for a general definition of the security needs of the region, regardless of the specific nature of the threat. This model aims to strengthen the comprehensive resilience of the assessed region to security threats and the risks they represent.

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