METHODOLOGY FOR FACTUAL JUSTIFICATION TO PRIORITIZE CRITICAL INFRASTRUCTURES DURING EMERGENCY POWER SUPPLY

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ABSTRACT

Large-scale blackouts with a long duration have serious impacts on society and can easily reach the dimension of a national crisis. Stable local island power systems, energized by the locally available population of decentralized power units can supply at least the most critical consumers and thereby decrease the potential damage of large-scale blackouts immensely. The research project LINDA developed such an isolated grid emergency concept, which was successfully verified both in transient simulations and in three field tests. Thus a technical solution is available.

The energy supply has to be in a non-discriminatory manner by law. But the limited generation capacity in an emergency supply situation may require the disconnection of loads with subordinate priority for society. This discrimination is only permissible, if it is based on objective reasons. Therefore, a methodology for factual justification of prioritized supply of critical infrastructures in emergency situations is presented.

INTRODUCTION

A study by the German government has shown, that long-term and wide spread blackouts can have a serious impact on society and even lead to a national crisis. The potential for damage of a blackout would be immensely decreased, if the provision of electrical energy for the most critical consumers could be maintained with help of decentralized generation units. [1]

The research project LINDA (Local Island Power Supply and Accelerated Grid Restoration with Distributed Generation Systems in Case of Large-Scale Blackouts) developed a general applicable concept for a stable emergency power supply, especially for critical infrastructures [2]. The concept, which is based on establishing and operating a stable isolated grid, that is supplied by the locally available mixture of distributed generation units, was successfully verified in a transient simulation model as well as in three field tests. [3] So a technical solution for an emergency power supply is available. As a result of the missing main grid, the availability of generation capacity is limited during an emergency supply. In case of a shortage of generation power, the operation of a stable local power island requires the curtailment of loads. Due to their importance for society, critical infrastructures like drinking water supply or hospitals should be prioritized in this situation. This is a conflict to the non-discriminatory access to electrical energy. The topic has been also targeted in the Austrian project SORGLOS [4], but an elaborated solution is missing.

Legal Framework

In general, the access to power supply in a non-discriminatory manner is obligatory for all customers by law. The non-discriminatory manner must also be ensured during emergency supply in accordance to the German Electricity Grid Access Ordinance. The responsibilities for the non-discriminatory power supply are allocated by transmission as well as distribution grid operators [StromNZV § 15 (2), (5)].

The German General Equality Law allows a prioritization and therefore a discrimination, when there is an objective justification by a legitimate aim [AGG § 3 (2)]. In the end, an absolute equality can only be reached, when nobody is supplied [5]. This leads to the question: Supplying critical infrastructures based on factual justification and therefore minimizing the damage on society or supplying nobody based on absolute equality? There is a similar problem in disaster medicine, with one clear answer. No medical supply is no option. Here, a factual justification of unequal treatment legitimates the medical supply of patients. [5]

The transfer of this approach to electrical emergency supply leads to the conclusion, that objective justified discrimination of individual consumers must be accepted to minimize social damage. The precise definition of a legitimated aim has to be complementarily proofed by legal department.

Based on the German General Equality Law, clear reasons are necessary to justify the prioritization of critical infrastructures in case of a shortage of generation power during emergency supply. Hence, a methodology for classifying customers with their importance to society is presented.

Interdependencies of Critical Infrastructures

Critical infrastructures supply general public with essentials. Hence, they are extremely important for society. Figure 1 shows eight common listed categories of critical infrastructures, which can be extended. The quantification of the interdependencies is according to [1]. The arrow from energy to food exemplarily means, that the dependency of food from energy is high. As shown in the figure, critical infrastructures are highly dependent on energy supply on the one hand and have complex mutual interdependencies on the other hand. Therefore, a reason-based methodology with a clear result is necessary to rank priority of loads.

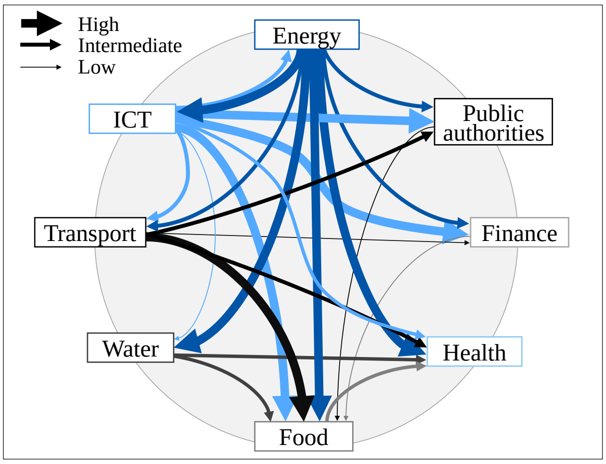


Figure 1. Interdependencies of Critical Infrastructures (Data basis by [1], own representation).

BASIC REQUIREMENTS FOR THE USAGE OF PRIORITIZED EMERGENCY SUPPLY

It is essential to differentiate the emergency supply from normal operation. As long, as an interconnected operation without curtailment of loads is possible, this has to be preferred in every case. If the main grid is not available for a long time, what means at least several hours, the following conditions are necessary for a prioritized emergency supply of critical infrastructures in an isolated grid:

- Islanding of the desired grid section is technically feasible
- Access to generation unit with black start capability in the isolated grid
- Operation concept for the isolated grid available (e.g. according to LINDA [2])
- Prioritized supply list

The methodology for elaboration of a prioritized supply list is explained in the following.

METHODOLOGY FOR THE ELABORATION OF A PRIORITIZED SUPPLY LIST

The elaboration of a prioritized supply list for emergency situations requires consideration of the load units' importance for society as well as technical prerequisites. In this paper, a load unit is defined as the smallest unit that can be technically integrated in the isolated grid, what means the smallest switchable unit. A load unit may or may not include a critical infrastructure.
In order to fulfil these conditions, a four-step methodology was developed, which is shown in Figure 2. The following steps are performed sequentially, with the output quantities of the previous step being the respective input quantities of the following step:

1. Ranking the relevance of load units for society using a rating matrix
2. Development of a priority list
3. Proof of technical feasibility
4. Development of a supply list

0. Necessary Data Basis

The following information is necessary in preparation for the application of the methodology. On the one hand technical requirements are necessary:

- Available generation power in the isolated network ($P_{Available}$)
- Maximum permissible load step for stable operation of the isolated grid
- Maximum load step and stationary power (P_{Load}) for all load units in the isolated grid

On the other hand, input values for the ranking matrix have to be determined. If the necessary information is given, the first step in the methodology according to Figure 2 is to rank the relevance of load units for society.

1. Ranking the Relevance of Load Units

As already mentioned, the complex interdependencies of different loads require a method of ranking the relevance of load units for society with a clear result. Therefore, a rating matrix with factual criteria is used to weight the relevance of loads with points. This procedure leads to a clear result in the end.

Categories and Criteria

The category contains the objective reasons, which are relevant for the justification of prioritization. The scaling factor (S) allows the scaling of the categories according to their relevance for society. The higher the scaling factor, the higher the weighting of the category.
The criteria are used to evaluate the pressure to act within a category. The weighting points (*WP*s) specify weighting of the single criterion with a range from 0 to 10 points. After defining the categories, setting the scaling factors and weighting points, the products ($S \bullet WP$) of each unit are filled in the rows. Afterwards, the values are summed up column by column, to get a score for each unit.
Figure 2 includes four examples of categories with their criteria. Category 1 is here the endangerment of human lives according to Article 2 of the German Basic Law [GG Art. 2 (2)]. This article contains the right to life and physical integrity. The criteria immediately, short-term and long-term are exemplarily defined according to [1]. The more urgent the endangerment, the more weighting points should be given.
The number of concerned people according to the rule of maximization [5] is a further example for category. The criteria can be graded in percentage (supplied people in relation to the number of affected people).
More examples represent the time horizon of damage and the economic damage. Since the rating of economic damage differs [6], a consistent methodology has to be applied for all units.

1. Ranking the Relevance of Load Units for Society Using a Rating Matrix

No.	Category	Scaling factor	Criteria	Unit A		Unit B		Unit …		Reference
		S		*WP*	*S • WP*	*WP*	*S • WP*	*WP*	*S • WP*	If available
1	e.g. endan-germent of human lives	e.g. 5	Immediately (e.g. < 8 h)	e.g. 10						GG Art. 2 (2): Right to life, [1]
			Short-term							
			Long-term (e.g. > 7 d)	e.g. 0						
2	e.g. number of concerned people	e.g. 4	Many (e.g. > 70 %)	e.g. 10						Rule of maximization [5]
			Intermediate							
			Few (e.g. < 20 %)	e.g. 0						
3	e.g. time horizon of damage	e.g. 2	Long-term (e.g. > 5 y)	e.g. 10						Urgency [5]
			Medium-term							
			Short-term (e.g. < 1 y)	e.g. 0						
4	e.g. amount of economic damages	e.g. 1	High (e.g. > 300 Mio. €)	e.g. 10						Costs of damage [1], [7]
			Intermediate							
			Low (e.g. < 0.5 Mio. €)	e.g. 0						
…										
Score (Sum of scaled weighting points)				**A**		**B**		**…**		

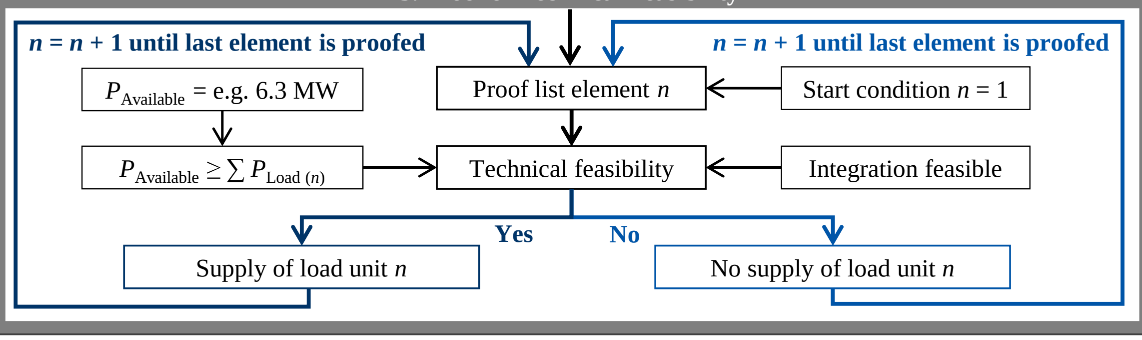
Score for each load unit

2. Development of Priority List

n	Load unit	Critical load	Descending order of scores	$P_{\text{Load}\,(n)}$ in MW
1	e.g. C	e.g. hospital	e.g. 37	e.g. 2.1
2	e.g. A	e.g. drinking water	e.g. 29	e.g. 0.9
3	e.g. D	e.g. police	e.g. 20	e.g. 1.3
4	e.g. B	e.g. ICT	e.g. 10	e.g. 2.5
5	e.g. F	e.g. food industry	e.g. 3	e.g. 1.8
…				
x	e.g. E	e.g. households	e.g. 0	e.g. 1.1

Priority list

3. Proof of Technical Feasibility



Technical feasibility of each load unit

4. Defining the Supply List

m	Load unit	Critical load	Descending order of scores	$P_{\text{Load}\,(m)}$ in MW	$P_{\text{Available}} - \sum P_{\text{Load}\,(m)}$ in MW
1	e.g. C	e.g. hospital	e.g. 37	e.g. 2.1	e.g. 4.2
2	e.g. A	e.g. drinking water	e.g. 29	e.g. 0.9	e.g. 3.3
3	e.g. D	e.g. police	e.g. 20	e.g. 1.3	e.g. 2.0
4	e.g. F	e.g. food industry	e.g. 3	e.g. 1.8	e.g. 0.2
…					

Figure 2. Methodology for Factual Justification to Prioritize Critical Infrastructures during Emergency Power Supply.

Further categories can be added, for example endangerment of the production of essentials or endangerment of animal lives. The categories and criteria of Figure 2 are proposals and can be replaced. The output of Step 1 is the factual justified sum of scaled weighting points (score) of each load unit. These scores are the input parameters for the priority list.

2. Development of Priority List

The priority list results of the descending order of the unit scores. In consequence of the descending order, there is an explicit ranking of the load units. Figure 2 shows an arbitrarily chosen example for a priority list.
The technical feasibility for the supply of individual list elements is a basic requirement. Thus, the proof of technical feasibility is described in the third step.

3. Proof of Technical Feasibility

The proof of technical feasibility is done for each element of the priority list in a sequential order. It includes the following aspects:

- $P_{\text{Available}} \geq \sum P_{\text{Load}\,(n)}$
- Check the integrability

$P_{\text{Available}}$ is the available generation power in the isolated grid and has to cover the sum of loads ($\sum P_{\text{Load}\,(n)}$). Thus, for each load unit is proofed in order of the priority list, whether the remaining generation power is sufficient. In Figure 2, the procedure is simplified and only shown for active power, the procedure for reactive power is analogous.
Furthermore, the technical integrability must be ensured. For this, the load unit has to be connectable and the resulting load step must not destabilize the isolated grid. The loop of proofing ends, when the last unit x is proofed. The result of Step 3 is an assessment for each load unit, whether it can be supplied for technical reasons or not. This is a necessary input for defining the supply list.

4. Defining the Supply List

In Step 4, the final supply list under consideration of the priority of load units and technical feasibility is set. The resulting list corresponds to the priority list adjusted for non-serviceable load units. This supply enables a prioritized supply of critical infrastructures in emergency situations, legitimized on basis of factual reasons.

CONCLUSION

Modern societies are vulnerable to large-scale blackouts with a long duration. Such events can cause huge damage. Therefore, the research project LINDA developed a concept for a stable emergency power supply based on decentralized generation units in isolated grids. This concept, which was successfully proofed in simulation and field tests, allows the emergency supply of critical infrastructures and thus the reduction of damage on society in case of a blackout.
The limited generation power in such an emergency situation can require the curtailment of load. This stands in conflict to the non-discriminatory access to electricity, what is set by law. Discrimination is only possible, if it is objectively justified. Hence, a methodology is presented, which allows the establishment of a prioritized supply list for emergency situations. The order of the list elements is based on a clear scoring system, which considers the importance of load units for society and the technical feasibility of supply.
This methodology can help to legitimize prioritized supply of critical infrastructures in case of a large-scale blackout and therefore to reduce the damage on society. The prioritization process is based on objective reasons and limited to emergency situations.

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ACTS AND REGULATIONS

AGG Allgemeines Gleichbehandlunggesetz from 14.08.2006, BGBl. I, p. 1897, last amended by Art. 8 G v. 3.4.2013 I 610.
GG Grundgesetz für die Bundesrepublik Deutschland from 23.05.1949, last amended by Art. 1 G v. 13.7.2017 I 2347.
StromNZV Verordnung über den Zugang zu Elektrizitätsversorgungsnetzen from 25.07.2005, BGBl. I, p. 2243, last amended by Art. 1 V v. 19.12.2017 I 3988.

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