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Preference Risk Assessment of Electric Power Critical Infrastructure

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Risk assessment represents a complicated process in the course of which a subjective deliberate distortion of results must be avoided. Simultaneously, the evaluator should however be allowed to take into account his/her own preferences that give him/her, in return, a possibility of maximum use of acquired results of this assessment. For this purpose, authors present the article that deals with the problems of preference risk assessment in the area of electric power critical infrastructure. The essence of preference risk assessment is the employment of multi-criteria analysis using the techniques of criteria hierarchy assessment or applying the methods based on quantification of utility function. Such a method of assessment enables the owners of electric power facilities and other stakeholders to prefer the assessment of specific risk kinds depending on the type of facility (generation, transmission and distribution) and the securing of required safety level.

When studying the preferences, this article starts from the premise that requirements for the level of safety of individual facilities within the electric power sector will differ according to specific type of electric power facility. However, the preferences will also differ according to opinion about the studied element, e.g. in the case of requirements concerning the effectiveness of operation (economic risk) or if the given element is studied as part of critical infrastructure. On this basis, it can be stated that it will not be possible to settle differences in the systems of preferences by means of creation of a single system of preferences, which will be universally applicable, but that it will be possible to settle them by means of several purpose-built systems. Possibilities of creation of such assessment systems are the subject of this contribution.

1. Introduction

The electric power sector represents one of the most significant and vulnerable areas of critical infrastructure. Electric power generation, transmission and distribution facilities are exposed to threats of various nature all over the world. Green Book on a European Programme for Critical Infrastructure Protection (Green Paper, 2005) states that *critical infrastructure can be damaged, destroyed or disrupted by deliberate acts of terrorism, natural disasters, negligence, accidents or computer hacking, criminal activity and malicious behaviour*.

Based on the above-mentioned facts it is necessary to identify and analyse all risks having negative effects on the functionality of the electric power sector. The necessity of the analysis of critical infrastructure risks follows from a Council Directive of the European Union (Council Directive, 2008). The risk analysis is understood in this case as the consideration of relevant threat scenarios with a view to assess the vulnerability and potential impact of critical infrastructure damage or destruction (Bernatík et al., 2013).

Following previous research (Řehák et al., 2013) it is evident that the most suitable way of assessment of risks in the electric power sector is the use of multi-criteria analysis (MCA), which can be defined as a model (Hajkowicz and Collins, 2007) containing: (1) a set of decision options (variants) which need to be ranked by the decision maker, (2) a set of criteria, and (3) a set of performance measures which make it possible to quantify each criterion for each decision option.

In addition to the above-mentioned standard variables, preferences of the given evaluator or specific interest groups in a form of implementation of weighting coefficients for individual criteria should be applied

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as well. From this point of view, the aim of the following text is the presentation of possibilities and background in the area of preference assessment of critical infrastructure risks.

2. Materials and Methods

As already mentioned in the introduction of the paper, as the most suitable way of assessing the risks in the electric power sector, the use of **multi-criteria analysis** can be regarded. At present, a number of MCA techniques that differ in their capabilities exist (see e.g. Figueira et al., 2005). Mathematically, the decision model can be formulated as follows (relation 1):

$$\max \quad u_i = \sum_{j=1}^{m} pm_{i,j} \cdot w_j \tag{1}$$

where utility *u* of variant *i*, defined as a sum of weighted (w) performance measures *pm* of the criteria *j*, is maximized. Definition (1) presumes that the criteria used in the decision analysis are independent of each other (Fishburn, 1965).

For the mathematical expression of preferences of the given evaluator or specific interest groups, it is suitable to implement weight coefficients for individual criteria. These weight coefficient can be determined either by using simple methods (e.g. point allocation method, weighted rank method, basic variant method, Fuller triangle method), or by using more complex methods based on the pairwise comparison of variants that support the evaluation of criterion hierarchies. Among the most suitable methods based on paired comparison of variants there are Analytic Hierarchy Process *AHP* (Saaty, 2008) and Analytic Network Process ANP (Saaty, 2004), and also methods based on the quantification of utility functions and their combinations (Weil and Apostolakis, 2001). In certain cases, the use of fuzzy logic (Djapan et al., 2013) can be suitable; however, in this article, authors do not take this path.

Regardless of the selected method, derived weights should always satisfy the conditions illustrated in Figure 1. It also follows from the figure that weight estimation itself should be done separately for individual levels of designed hierarchies.

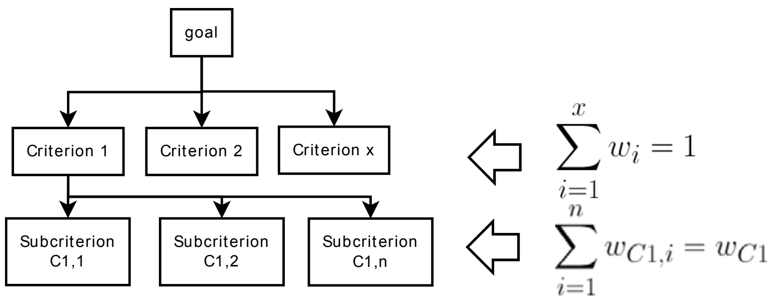

Figure 1: Weight calculation using the AHP method

When **studying the preferences**, this article is based on the fact that requirements for the level of safety of individual facilities in the framework of the electric power sector will differ by facility type. Above all, it is necessary to distinguish facilities for electricity generation from electricity transmission and distribution facilities. However, the preferences will also differ by opinion about the studied element – other preferences will be in the case of requirements for the efficiency of operation (economic risk); nevertheless, preferences can change significantly if the given element will be studied as part of critical infrastructure. It will not be possible to settle differences in the systems of preferences by means of creation of a single system of preferences, which will be universally applicable, but it will be possible to settle them by means of several purpose-built systems. In this article, a possibility of building just such an assessment system is studied.

3. Multi-criteria Analysis of Risks Associated with Electric Power Facilities

The essence of the multi-criteria analysis of risks associated with electric power facilities is risk assessment by means of pre-determined criteria using a semiquantitative method of assessment. In the first stage, the areas for which corresponding assessment criteria will be defined have to be delimited. Identification as well as definition of the criteria is made by the evaluator according to his/her own opinion. Nevertheless, it would be however suitable to find these criteria by the consensus of significant stakeholders. In the second stage, detailed specification of these criteria is carried out and corresponding index values are determined by means of a similar mechanism. In the third stage, relations for risk calculation are formulated and reference values for the determination of final risk level are defined (Řehák et al., 2013).

The basis of multi-criteria analysis of risks associated with electric power facilities is the definition of criteria (see Figure 2) used in the course of assessment. These criteria are, in relation to the assessment of facilities for electricity generation and transmission, divided into three fundamental groups (Řehák et al., 2013): (1) criteria related to the assessment of the level of vulnerability of facilities, (2) criteria related to the assessment of the level of dangerousness of threats, (3) criteria related to the assessment of the level of safety measures.

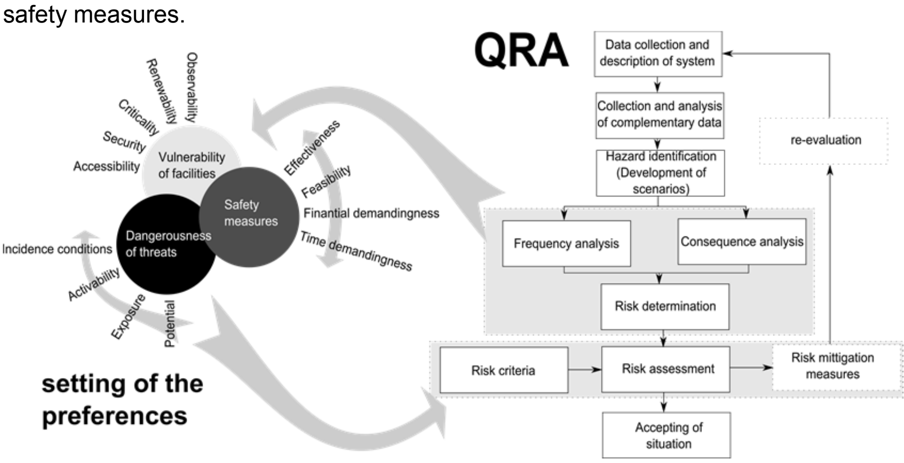

Figure 2: Criteria for the assessment of risks associated with facilities and their implementation into Quantitative Risk Assessment method

Criteria set like that are further specified and corresponding index values are assigned to them. A specific example of the specification and indexing of a criterion “Criticality” is worked out in Table 1.

Table 1: Specification and indexing of the criterion “Criticality”

Specification of criterion “Criticality”	Index value of the criterion
Negligible criticality (asset is an easy to replace part of the system and its damage or retirement will have almost no impact on the functionality of the concerned part of the system)	1
Low criticality (asset is a replaceable part of the system and its damage or retirement will have no significant impact on the functionality of the concerned part of the system)	2
Significant criticality (asset is a difficult to replace part of the system and its damage or retirement will have a serious impact on the functionality of the concerned part of the system)	3
High criticality (asset is a very difficult to replace part of the system and its damage or retirement will have a serious impact on the functionality of the whole system)	4
Absolute criticality (asset is an irreplaceable part of the system and its damage or retirement will have a critical impact on the functionality of the whole system)	5

Criteria set like that ensure the objective assessment of risks associated with the electric power facilities; nevertheless they do not take into account in any way the preferences of the given evaluator or other interest groups, such as Ministry of the Interior (which is in the Czech Republic responsible for critical infrastructure protection) and Ministry of Industry and Trade (that is in the Czech Republic responsible for the functionality of the electric power sector). For this purpose, possibilities and background in the area of preference risk assessment of electric power critical infrastructure are studied below.

4. Preference Risk Assessment

The preference assessment of risks enables the evaluator to implement subjective conditions into the otherwise objective process of risk assessment. In this way it gives a possibility of partial influencing the assessment by means of preferences of certain criterions over others. This part of the assessment process is important because each subject perceives the risks from its own point of view, which subsequently creates room for discussion of all stakeholders and for selection of the most suitable safety measures.

4.1 Differences in Preferences of Interest Groups

In the area of electric power critical infrastructure, three basic groups of stakeholders, having a rightful interest in the determination of infrastructure safety, exist, namely:

- state administration bodies (henceforth referred to as “state”),
- owners of individual infrastructure elements (i.e. electricity generation facilities, eletricity transmission facilities and electricity distribution facilities),
- other stakeholders (e.g. investors, suppliers, users, local self-government).

The primary interest of the state is ensuring the basic services provided to its inhabitants and to other persons who are currently in its territory. Interests of the owner of the element, whose basic aim is the realization of a benefit following from investment into the ownership of the infrastructure either directly in a form of paying dividends on the profit of the firm or indirectly by increasing the value of the firm, take a stand against these interests to a certain extent. The situation can be more complicated if the state is simultaneously the owner of the energy firm. In the world, this is not any quite unusual arrangement.

As far as the level of protective measures is concerned, the state usually prefers the implementation of effective measures (in the sense of maximally effective ones) regardless of financial requirements for solution up to certain limit permissible financial demandingness hurting the ability of a private owner to take profits. The private owner prefers maximally effective solutions from the point of view of final measures and financial means necessary for the implementation of these measures. The interest of the private owner is the minimization of investment in safety, but merely to the minimum permissible amount that will ensure the maximum profit from infrastructure operation and minimum safety requirements specified in valid legislation and also other agreements made e.g. in the framework of collective bargaining, etc.

The state owner of the energy company is thus placed in a tough position. Realization of owner’s preferences may negatively affect economics of the company. In addition to safety interests, other economic interests can play a role here, e.g. in the area of employment, the state also can in the firms in which it has a shareholding to collect part of profit directly in the form of income tax and indirectly in the form of dividend payout.

The current economic situation and certain public budget strain can create political pressure on the preference of economic parameters of operation.

If the state has not at least a minority shareholding in the energy company, it cannot participate directly in management and thus has not any instruments for direct influencing the selection of measures themselves and potentially the time horizon of their implementation. This situation is usual in many advanced economies, such as the USA, Great Britain, Federal Republic of Germany, and others. The level of safety can be then influenced by the state only by means of indirect modification in the common legislative environment, in which energy companies act – especially laws, regulations and also engineering standards, and then subsequently by means of the method of enforcing them.

4.2 Preference Mapping

Preference mapping represents a necessary condition for the correct determination of preference weights of individual coefficients (Řehák et al., 2013). Results of preference mapping given below were obtained based on discussion with representatives of the following interest groups:

- representatives of owners of critical infrastructure elements,
- representatives of the state in companies owning critical infrastructure elements (where the state has an ownership interest),
- government employees in the area of critical infrastructure safety.

Finding the preferences is, from the technical point of view, very complicated in the case of a group of representatives of the state in supervisory boards of energy companies, because a relatively small number of these companies exist and their supervisory boards consist of a small number of persons. For instance, in the Czech Republic, the Board of Directors of the company CEZ is composed of 12 members and the representatives of employees form one third of them (by law). Thus it is practically impossible to create a statistically representative set of data illustrating the preferences of the representatives even in the case that all members of the Supervisory Board would be prepared to provide these data.

Combination of data from several states is then problematical because different states enforce different preferences not only according to their historical development, but also e.g. as a result of large-scale incidents (extensive or repeated power failures, terrorist attacks, etc.) that have already affected them.

In the case of two remaining interest groups, preference mapping is possible. Preference mapping should be again performed separately in individual states. In this case, the possibility of applicability of ascertained data is much easier (especially in the EU countries), namely mainly thanks to the approximation of legislative bases and also to standards, etc. However, it will be necessary to verify the possibility of applicability by a comparative study of individual states.

4.3 Implementation of Preferences into Risk Assessment

The basic precondition for the successful implementation of preferences of interest groups to the process of risk assessment is realistically determined weights. On this basis, an AHP method (Saaty, 2008), often used for this purpose in practice (De La Canal and Ferraris, 2013) and providing good results, was selected. Another significant factor of selection of this method is the fact that it contains mechanisms enabling the evaluation of measurement consistency using a quantity called consistency ratio (CR). This quantity indicates a random index in the case of measuring the preferences of criteria, when a value 0.1 indicates an acceptable consistency index and 0.9 corresponds to purely random selection.

This is of special importance because the basic materials for preference mapping in this publication were not formulated based on “hard” data, but were formulated based on rather “soft” feelings following from consultations. Moreover, the results presented below cannot be regarded as final results; they can be regarded rather as an effort to prepare the basic materials for carrying out a good-quality formal survey to make these results more accurate.

For the hierarchy of criteria from Figure 2, the following results were obtained (see Table 2). In the first step of preference assessment of criteria, weights for individual areas are to be determined. In this case the weights were equally divided to areas increasing the risk (i.e. vulnerability of facilities and dangerousness of threats) and areas decreasing the risk (i.e. safety measures).In the second step, criteria for individual areas were evaluated using the AHP method (Saaty, 2008).

Table 2: Results of calculation of weights of criteria indicating preferences of the owner and the state

Area	Weight of area	Criterion	Weight of criterion (owner)	Weight of criterion (state)
Vulnerability of facilities	0.5	Observability	0.025	
		Renewability	0.068	
		Criticality	0.240	
		Security	0.110	
		Accessibility	0.063	
	Consistency ratio (CR)		0.120	
Dangerousness of threats	0.5	Incidence conditions	0.060	0.160
		Activability	0.030	0.040
		Exposure	0.070	0.140
		Potential	0.350	0.160
	Consistency ratio (CR)		0.032	0.012
Safety measures	1.0	Effectiveness	0.150	0.640
		Feasibility	0.150	0.200
		Financial demandingness	0.650	0.120
		Time demandingness	0.060	0.040
	Consistency ratio (CR)		*0.012*	*0.180*

The above-mentioned results describe differences in preferences of interest groups of owners of facilities and also interests of the state that sees the facilities differently. From the point of view of consistency of set weight coefficients, it can be said that the “safe” limit of CR is 0.1. This value was exceeded slightly in the case of vulnerability of facilities and then more markedly in the case of safety measures on the part of the state. In both the cases, what is meant is the price for the use of “soft” data and thus it is necessary to emphasise again rather an approximate character of the results.

What is interesting is also the relatively marked difference between the preferences of the state and those of the owner in the case of safety measures concerning the criteria of effectiveness and financial demandingness. This result could be interpreted as follows: the state pushes strongly on the implementation of safety-oriented measures which the owner tries to avoid or tries to implement such measures which will be as cheap as possible. The difference in the interests is, from this point of view, understandable; what is interesting is however the strength of these preferences.

A cause of this difference can be seen in several areas. The Czech Republic is a relatively young society and thus any consensus adopted by the whole society, concerning an acceptable level of risk (socially and economically) has not need to be formed here yet. This explanation is supported by indications from other fields, such as construction industry, where the Czech Republic has invested significantly in safety measures for newly constructed road tunnels. The cause thus could consist in the strong aversion of

Czech Republic's society towards risk. This would also argue considerably against the possibility of the application of preference data to other states that do not share such risk aversion.
Another possible explanation of different preferences of the state and of the owner (e.g. in the area of effectiveness and financial demandingness of implementation of safety measures) is inconsistency in the selection of preferences that reflects on the higher value of CR (0.012 versus 0.18). Nevertheless, it will be necessary to verify this possibility by further research and especially by "hard" data acquisition by means of a questionnaire survey.

5. Conclusion

The preference risk assessment of electric power critical infrastructure enables stakeholders (especially owners and the state) to make subjective assessment of risks associated with facilities based on preferred criteria. Subsequently, such assessment enables more effective communication with the other stakeholders and implementation of appropriate safety measures.
The above-presented results are an example of implementation of preferences of criteria of both the owner of the electric power facility and the state into risk assessment. For the determination of weights the AHP method utilising the direct comparison of significances of individual criteria was employed. Simultaneously, it is necessary to emphasise that in this case the specification of preferences was carried out by the authors themselves based on acquired information. However, the authors are indifferent towards both the groups. From the results of the assessment it is obvious that if respondents were to select between such criteria as effectiveness and financial demandingness, i.e. safety versus money, a possibility of intentional influencing the results (i.e. strategic bias of respondents), which could deteriorate the effort to map without prejudice the preferences of significant groups of users, cannot be excluded. For this reason, the authors do not recommend such direct preferences; they recommend such composition of questions that they will not be too suggestive from the point of view of the assessment method.

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