# APPLICATION OF NEW METHOD OF MULTI-CRITERIA ANALYSIS

**L. Juřica, Z. Hradílek, J. Dvorský, P. Krejčí**

[a])VŠB-TU Ostrava,17.listopadu 15 Ostrava-Poruba, 70833, Czech Republic
e-mail:leos.jurica.fei@vsb.cz, zdenek.hradilek@vsb.cz, jiri.dvorsky@vsb.cz, petr.krejci@vsb.cz

**Summary** The increase of reliability of electrical networks can be achieved for example by use of new components. That modernisation is considerably expensive. Therefore close attention is paid to selection of new components and place of their position. The use of methods of multi-criteria analysis is suitable for this decision making.

## 1. INTRODUCTION

For increase of reliability of distribution networks is used compensation older, manual controlled breakers to new, remote controlled, bud more expensive elements.

With regard to prize of these elements, we must with help of mathematical formulas choose only those elements, which are most acceptable. New methods of multi criteria analysis give us possibility to better choose substitute elements.

## 2. MCA – COMMON ANALYSIS

The multi-criteria analysis (MCA), as the name itself indicates, deals with the evaluation of particular alternatives according to several criteria. The term "alternative" designates each of the solutions of the selection report. The "criterion" is a property that is being evaluated with the given alternative. To each criterion such as weight is assigned that expresses the importance of particular criteria with regard to the others.

Following methods appear as advisable methods for solution of existing problems:

- Ideal point analysis (**IPA**)
- Technique for Order Preference by Similarity to Ideal Solution (**TOPSIS)**
- Concordance-Discordance analysis (**CDA**)
- **AGREPREF** method

In next sections, we describe calculation of method multi criteria analysis helped by AGREPREF method, others, as remarked above methods are describe in literature [3].

The initial step of each MCA analysis is to form an evaluating matrix - the elements of it reflect the evaluation of particular criteria for each alternative. The matrix *S* consists then of elements $S_{ij}$ where $i = 1, .. I$ alternatives and $j = 1, .. J$ criteria.

The evaluating matrix:

$$S = \begin{matrix} S_{11} & \dots & S_{1J} \\ \dots & & \\ S_{I1} & \dots & S_{IJ} \end{matrix} \qquad (1)$$

Because particular evaluations are not mostly measured against the same units, it is necessary to carry out the standardization of the matrix to the standard condition. For the case when the higher evaluation of the criterion means also the better evaluation (i.e. 1 = max, 0 = min), we can write the standardization as follows:

$$e_{ij} = \frac{S_{ij} - \mathrm{nin}S_{ij}}{\max_i S_{ij} - \min_i S_{ij}} \qquad (2)$$

$$e_{ij} = \frac{\max_i S_{ij} - S_{ij}}{\max_i S_{ij} - \min_i S_{ij}} \qquad (3)$$

## 3. AGREPREF METHOD

AGREPREF method go from presumption, that we are looking for minimum distance to a given variant from ideal variant, that is variant for which all value criteria run to best value. Ideal variant is mostly only hypothetical.

Method AGREPREF is best for tasks, when we've engaged decisive set of variants A=(a1, a2, …ap) and system of criterions f1, f2, …fk. Then we can define degree preference variant ai before variant aj.

$$S_{ij} \in \langle 0,1 \rangle \qquad (4)$$

Simultaneously we presume that we've booked up relative importance single criteria in forms of balances:

$$v_1, v_2, \dots, v_k \ , \ v_h \geq 0 \qquad \sum_{h=1}^{k} v_h = 1 \qquad (5)$$

For every couple of variants ai and aj, we aggregate criterions, which:

- prefer variant $a_i$ before $a_j$, set their indexes mark as $I_{ij}$
- prefer variant $a_j$ before $a_i$, set their indexes mark as $I_{ji}$
- they have for both variants equivalent values and from viewpoints of these criteria they are indifferent, set their indexes mark as $I_{i'j}$

Degree of preference variant $a_i$ before $a_j$ is:

$$S_{ij} = \sum_{h \in Iij} v_h \qquad (6)$$

Degree of preference variant $a_j$ before $a_i$ is:

$$S_{ji} = \sum_{h \in Iji} v_h \qquad (7)$$

Degree of indifference variants $a_i$ and $a_j$ is:

$$S_{i\acute{}j} = \sum_{h \in Ii\acute{}j} v_h \qquad (8)$$

With regard to term $\sum_{h=1}^{k} v_h = 1$ reads:

$$S_{ij} + S_{ji} + S_{i\acute{}j} = 1 \qquad (9)$$

Objectives of next progress are getting resultant preferential relation R = (P, I, N), after that would was possible order the variants. (P – relation of preference, I – relation of indifference, N – relation of repugnance ).

Rule of majority is simplest way to obtain relatin R = (P, I):

When, that $S_{ij} > S_{ji}$, then variant $a_i$ is preferred before variant $a_j$ ($a_i$ P $a_j$).

When $S_{i\acute{}j} = 1$, or $S_{ij} = S_{ji}$, then both variants $a_i$ and $a_j$ are indifferent.

AGREPREF is based on generalization of rule of majority. In this method are used two thresholds of sensitivity (threshold of indifferent and threshold of preference).

**Threshold of indifferent** α show, how big should be total sum of weight of those criterions, from whose viewpoints, are both variants $a_i$ a $a_j$ indifferent.

**Threshold preference** of both variants β show, how big should be total difference between total sum of weight of criterions, from whose viewpoints is variant $a_i$ preferred between variant $a_j$ and total sum of weight of those criterions, which preferred variant $a_j$ before variant $a_i$.

Values of all thresholds are in interval 0 – 1, $\alpha,\beta \in \langle 0,1 \rangle$. Relation of indifferent I is depends on threshold α, relation of preference P is depend on both thresholds α ,β. In special case (α = 1, β = 0) we have rule of majority.

When we compare all couples of variants, we progress according to graph on Fig. 1.

Final relation R = (P, I, N), which we get helped by comparing couples of variants, by graph on Pict.1. This relation is non-complete preferential relation, which must be transitive, its necessary to approach it by relation of semi-sorting, which is kvazi-transitive.

Relation of preference, we can show helped by graph, where bundles are variants $a_i$, i = 1, 2, …, p and oriented edges show, that $a_i$ is preferred before variant $a_j$. Elements of matrix of preference P are defined:

$$P = \begin{cases} 1 & \text{If } a_i \text{ is prefered before } a_j \\ 0 & \text{If } a_i \text{ is not prefered before } a_j \end{cases} \qquad (10)$$

We have to provide transitivity of relation P, it is why we make transitive cover, it is, that we in matrix change some values 0 to 1 that way, so as in all matrix must be: If $P_{hi} = P_{ij} = 1$, than also $P_{hj} = 1$.

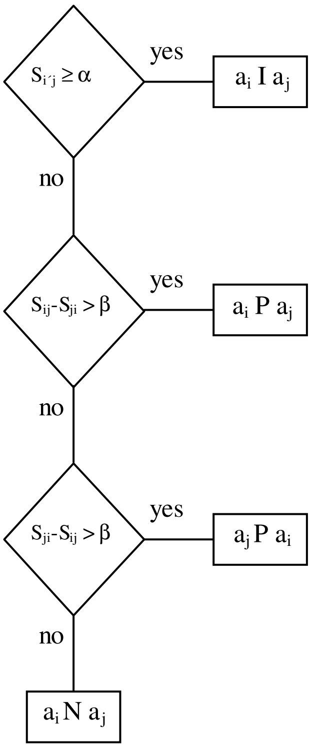


*Fig.1. Comparing all couples of variants*

We have to provide transitivity of relation P, it is why we make transitive cover, it is, that we in matrix change some values 0 to 1 that way, so as in all matrix must be: If $P_{hi} = P_{ij} = 1$, than also $P_{hj} = 1$.

Objective is to take sort rows and columns on that shape of matrix of relation P, when elements with value 1 are only in upper triangle matrix and separated from elements with values 0 by step-border. To this sorting of matrix we use $d_h$ index, which indicate difference between numbers of variant, before what is variant preferred and numbers of variant, where are preferred before given variant. We can determine it, as show:

$$d_h = d_h^+ - d_h^-, \text{ where}$$

$$d_h^+ = \sum_{j=1}^{P} P_{hj} \qquad d_h^- = \sum_{i=1}^{P} P_{ih} \qquad (11)$$

When we sort rows and columns according to decreasing value of $d_h$ we will be closer to searched shape of matrix P. If minimal one element on diagonal also under diagonal have value 1, than graph of relation accordant with transitive closer P contain cycle, which we can remove by change this value from value 1 to 0.

Founded shape of sequence cannot contain step border between area with elements 1 and area with elements 0. It we can do by gradual changing values 0 and 1 in zone of indeterminateness, which contain elements 1 and 0. For changing elements in zone of indeterminateness there exist some helpful procedures. With new sort by new values $d_h$ we get searched shape of matrix P.

Final matrix is matrix of semi-sorting. Values $d_h$ according to final matrix and determines kvasi-sorting of variants.

## 4. APLICATION TO REMOTE CONTROLLED DISCONECTORS IN DISTRIBUTION NETWORK 22KV

As a practical illustration of multi criteria analysis, for concrete breakers in distribution network was chosen file of 69 breakers (alternates), which was evaluated by methods AGREPREF, IPA a TOPSIS. For evaluating ways chosen this criterions with weights:

1) distance of breaker, from breakdown service (*weight 0,158*)
2) number of operating manipulation (*weight 0,166*)
3) number of manipulation, when failure (*weight 0,170*)
4) inaccessibility (*weight 0,067*)
5) charge of line in place of breaker (*weight 0,066*)
6) necessity of manipulation, when searching failure (*weight 0,180*)
7) energy (*weight 0,128*)
8) economic return of amount investment (*weight 0,065*)

*Tab. 1. Example of input data (10 of 69 elements)*

| Criterion / Alternative | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | 17 | 5 | 10 | 0,5 | 30 | 0,5 | 4763 | 18,40 |
| 2 | 15 | 6 | 8 | 0,25 | 65 | 0,5 | 8669 | 16,48 |
| 3 | 14 | 4 | 6 | 0,5 | 25 | 0,5 | 2461 | 28,34 |
| 4 | 8 | 5 | 10 | 0 | 80 | 1 | 12702 | 15,97 |
| 5 | 7 | 4 | 5 | 0,75 | 40 | 0,5 | 3366 | 34,11 |
| 6 | 8 | 5 | 10 | 0 | 80 | 1 | 12702 | 15,97 |
| 7 | 6 | 3 | 5 | 0,75 | 25 | 0,5 | 2024 | 42,11 |
| 8 | 10 | 5 | 10 | 0,75 | 60 | 0,5 | 9526 | 17,63 |
| 9 | 12 | 5 | 10 | 0,75 | 50 | 0,5 | 7939 | 18,05 |
| 10 | 13 | 5 | 10 | 0 | 50 | 0,75 | 7939 | 17,54 |

Input data was analyzed by MCA8, which was developed on department of power engineering, with help department of informatics.

This program serves for calculation of problems of multi criteria analysis, by methods TOPSIS, WSA, IPA and AGREPREF and also too for editing weights of criterions. Input data can be inserted just in program interface, or like table from MS Excell. Output data could be exported to MS Excell or special .mca files.

In next progress this software will be added possibility calculating CDA method and calculating of weights of criterions.

Here are screens of MCA8, where is view of interface of this software.

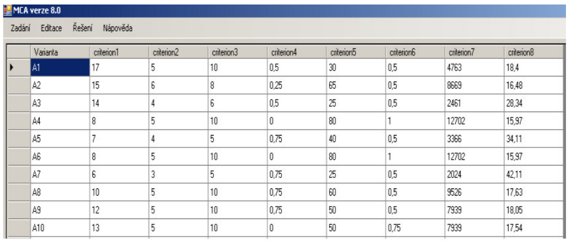


*Fig. 2. Example of input data in MCA8*

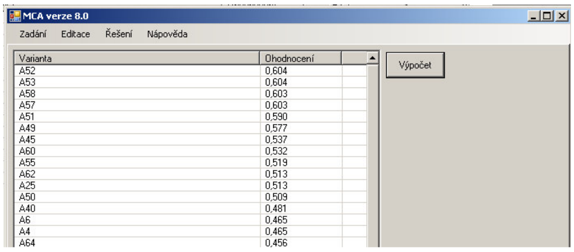


*Fig. 3. Output data from TOPSIS method, example of resulting sequence of alternatives*

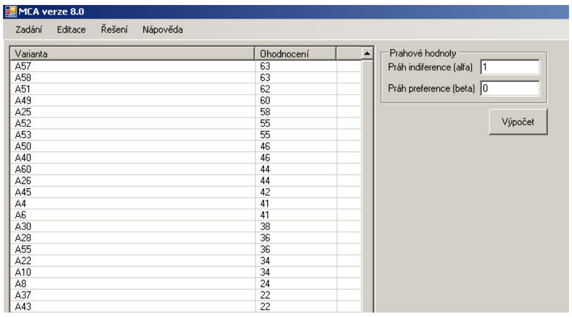


*Fig. 4. Output data from AGREPREF method, example of resulting sequence of alternatives*

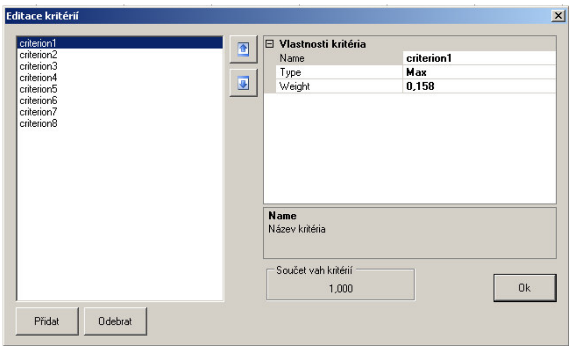


*Fig. 5. Example of editing weights of criterions*

## 5. CONCLUSION

Application of the systems of remote-controlled components for acceleration in handling and thus shortening of duration of a fault in the network. This results in rising of probability of faultless service and then the reliability of electrical energy supply. When deciding where to apply these components the multi-criteria analysis can be advantageously used. A weight is assigned to each criterion. It expresses the importance of particular criteria in relation to the others. AGREPREF method is now developed in department of power engineering a bring good results. IPA, WSA and TOPSIS methods can be recommended to be used at the beginning of solving the investment designs. The AGREPREF method is more complicated and it is suitable for final decision-making for this reason with emphasis put on the objectivity of the final solution. In the course of calculation of criteria weights the greatest problem is the acquisition of input data. This data has subjective character caused by the reviewers; consequently the number of reviewers should be reasonable and the reviewers should know well the query.

Because mathematical calculation in multi criteria analysis is not simple, and very time consuming, on department of power engineering, with help of department of informatics was developed software MCA8 for calculation by more methods. This software is still developing and beating up.

**Acknowledgment**

This work is supported by research purpose No: MSM 6198910007.

## REFERENCES

[1] Gurecký J.: *Optimalizace řízení sítí vn dálkově ovládanými úsečníky (Optimisation of HV network management by remote-controlled section switches)*, doctoral dissertation, Ostrava 1998

[2] Fiala P., Jablonský J., Maňas M.: *Vícekriteriální rozhodování*, Praha 1996

[3] Krejčí P.: *Řešení spolehlivosti dodávky elektrické energie v oblasti s dálkově ovládanými prvky v sítích vysokého napětí (Solving the reliability of electrical energy supply in region with remote-controlled components in medium voltage networks)*, doctoral dissertation, Ostrava 2001

[4] *Korviny P.: Aplikace multikriteriální analýzy při nasazování dálkově řízených prvků v distribučních sítích vysokého napětí (Application of multi-criteria analysis by introduction of remote-controlled components in distribution medium voltage networks), doctoral dissertation, Ostrava 2003*