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NEW CRITERIONS FOR OPTIMAL DEVELOPMENT AND EXPLOITATION NETWORK THE STATISTICAL SELECTIVITY AND RELATIVE SENSITIVITY

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1. INTRODUCTION

The distribution networks have, in general, redundancy selectivity. We are proposing in this paper the concepts of statistical selectivity and sensitivity as being criterions of development and exploitation of the electrical networks.
The authors present the relationships and the algorithms by which this criterion can be applied to the defect location in the distribution network and to the optimization of the location of the switching electrical equipment in the network bus.
The quality control of the provided energy by the medium-voltage distribution networks is an important request, which impose a superior management in this network too. Especially for the medium-voltage distribution network, we fixed norms referring to the indicators, as: the turning off number and their duration to the customers. This problem asks clear answers to a lot of simple questions, as:

- which is the most efficient way to equip the feeders taking into account that there are more possibilities, for example: the supplementary switchers of sectioning installation, the fit up of defect detectors, remote control installation, etc.;
- which is the degree in which the equipment participate to the accomplishment of a certain level of reliability of the medium-voltage network and which must be objectives to follow for a possible retechnology occurred in a given network;
- on which quality level of the alimentation with electrical power service could be hired, by the provider, the agreement warranties for a customer, in the case of a given configuration for the medium-voltage network;
- which is the optimal succession of operations for the location and the elimination of the damages which appear in a given network;
- The solving of these problems is directly connected to the **selectivity** concept, which we define as the capacity of the network to allow isolating the faults without perturbations, or with the minimum perturbation of the customers connected to its areas.

As a matter of fact the selectivity is directly connected to the equipment degree of the network bus with switching electrical equipment (switchers, disconnectors, recloser, etc) and also to the protection and remote control degree.
The network sensitivity we will define as the way in which a fault from an area of the network affects the customers connected to others different areas. Unlike the selectivity that is most a qualitative

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concept, the sensitivity is expressive, as we will see next, by quantitative values (periods and numbers of turning off, undelivered energy, damages caused by the turning off).
To define these notions it is necessary a deep analyze of the dynamical working of the network.
Both concepts are useful at the corrective maintenance operations and this means at the location of the defects in those networks which are realized by the system engineering throw sequential orders and at the establishing the number and the place of the switching electrical equipment to the networks outgrowth. And the order of commutations for the defect location needs to consider the random character of the defects, shaped on statistical patterns. Also these notions can be very useful to compare different configurations of distribution networks. This concept can be defined also as **selectivity** respectively **statistical sensitivity**.
In this paper we asset all these by proper examples or taken from the literature [1], also from others authors papers [3].

2. THE SENSITIVITY OF A DISTRIBUTION NETWORK

In accordance with the previous definition the sensitivity measure the degree in which a defect from area of the network affect the customers from the others areas. Under the simplest form, the affection can be defined as the turning off time of the alimentation with electrical power of the customers from an area, corresponding to a fault from another area. This one can be expressed as matrices, as we will see next.

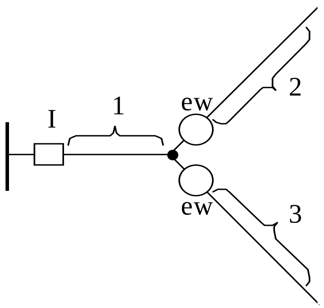

Figure 2.1a Radial network

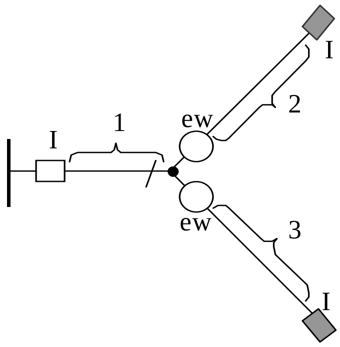

Figure 2.1b Closing a loop network with radial function

For example, for a single network, like those from figure 2.1, with three areas (1, 2 and 3), which can be supply radial (2.1a) or closing a loop (2.1b), the sensitivity expressed as the afferent times of an defect is given in the tables 2.1a and 2.1b.

Legend:

Events:	
Gt	Voltage down (low voltage for short time)
Î	Turning off (absence voltage)
Tc	Commutation time
Td	Movement time
Tl	Location time
Tr	Repair time

ew – equip way:	
Î	Switcher cells (circuit breakers)
Sc	Command disconnectors (automatic command)
Sn	Uncommand disconnectors (manual command)
Cc	Signal flag (signal device)
Fc	Without signal flag
N	Nothing

Table 2.1a – RADIAL NETWORK

AFFECTED AREA		DEFECT AREA 1	2						3					
		Î, Sc (Cc, Fc), Sn (Cc, Fc), N	Î	Sc Cc	Sc Fc	Sn Cc	Sn Fc	N	Î	Sc Cc	Sc Fc	Sn Cc	Sn Fc	N
1	I	I (Tr)	Gt	I (Tc)	I (Tc+Tl)	I (Tc+Td)	I(Tc+Tl+Td)	I (Tr)	Gt	I (Tc)	I (Tc+Tl)	I (Tc+Td)	I(Tc+Tl+Td)	I (Tr)
2	Î, Sc (Cc, Fc), Sn (Cc, Fc), N	I (Tr)	I (Tr)						Gt	I (Tc)	I (Tc+Tl)	I (Tc+Td)	I(Tc+Tl+Td)	I (Tr)
3	Î, Sc (Cc, Fc), Sn (Cc, Fc), N	I (Tr)	I (Tc)	I (Tc)	I (Tr+Tl)	I (Tc+Td)	I(Tc+Tl+Td)	I (Tr)	I (Tr)					

Table 2.1b – CLOSING A LOOP NETWORK WITH RADIAL FUNCTION

AFFECTED AREA		DEFECT AREA 1	2						3					
		Î	Î	Sc Cc	Sc Fc	Sn Cc	Sn Fc	N	Î	Sc Cc	Sc Fc	Sn Cc	Sn Fc	N
1	I	I (Tr)	Gt	I (Tc)	I (Tc+Tl)	I (Tc+Tl)	I(Tc+Tl+Td)	I (Tr)	Gt	I (Tc)	I (Tc+Tl)	I (Tc+Td)	I(Tc+Tl+Td)	I (Tr)
2	Î, Sc (Cc, Fc), Sn (Cc, Fc), N	I (Tc)	I (Tr)						I(Tc)	I (Tc)	I (Tc+Tl)	I (Tc+Td)	I(Tc+Tl+Td)	I (Tr)
3	Î, Sc (Cc, Fc), Sn (Cc, Fc), N	I (Tc)	I (Tc)	I (Tc)	I (Tc+Tl)	I (Tc+Td)	I(Tc+Tl+Td)	I (Tr)	I (Tr)					

These dates stay to the base of the expression of the statistical sensitivity, which takes also into account the frequency of the defects in an area where the times from the matrices are replaced with:

1. Total periods of turning off in a given period:

$$MUT_{ji} = F_i \; x \; T_{ij} \qquad (2.1)$$

where:

- MUT_{ji} is the total time of the turning off of an area *j* because of the effects from area *i*;
- F_i is the defect frequency in area *i*;
- T_{ji} the value from the previous table.

2. Undelivered total energy in which the 2.1 formula is introduced the demanded power in the area, or the number of customers affected, multiplied with their affection period or with prejudice cause by the turning off.

3. THE STATISTICAL SELECTIVITY, AN OPERATION MANAGEMENT CRITERION

3.1 Network description

The medium voltage lines are characterized by the fact that a defect is eliminated in random times, determined by the defect finding, its isolation by local commends or from distance, and the consumer supplied. These can last from few seconds to few minutes for the same defect type.
Analyzing any distribution networks which we divide in a corresponding number of areas (sides or groups of isolated sides by switching elements) it results that any of the areas that forms it can be seen under two different view. From the first point of view the areas are capable of generating a defect, and from another point of view they can be influenced by other areas, from the point of view of the delivered energy quality of the customers. Using the matrices, which express the sensitivity, we can compose the scenery of reconfiguration of the network after any of the defect for supplying, as fast as possible, the costumes. For making up this scenery the operator needs some rules that should be included into a special algorithm.

3.2 The sequential reconfiguration

The operator must isolate the generation's source by the damaged areas in a gradual way and must supply the healthy area. The criterions, after which we reestablish the healthy area alimentation, suppose the establishment, from the beginning, of a list of priorities for the functioning of the switching equipment from the network.
First, we will activate the remote-controlled equipment, then will inventory the defects indicators which have functioned, for the establishment the next steps in the network re-configuration.
The difficulties appear in the places where the operator has incomplete information because only some of the equipment has defect indicators. This case we can broach the problem solving by tests and by applying the so-called way of broaching "experience and errors".
In the case of the unworking switching equipment, we pursue the application of some alternative solutions, chosen on the same base of limiting the turning off effect. For the success of this reasoning it is necessary to take into account all or as many as possible from the possible solutions of solving the problem. To every step of the previous reasoning we have to take into account the consequences referring to each area. The sensitivity matrices done that it is easy to make up the scenario.

4. THE APLICATION OF THE SENSITIVITY ANALYSE TO THE DIVIDING OF A RADIAL AREA

We will note the total average of the turning off for the period *T*, to the area *1* with:

$$MTTD_1 = q \cdot T = \frac{\lambda_1}{\lambda_1 + \mu_1} \cdot T = \frac{L\lambda_0}{L\lambda_0 + \mu_0} T \qquad (4.1)$$

L – the length of the area line (we neglected the others elements of the area).
Considering $L\lambda_0 <<< \mu_0$, it results:

$$MTTD_1 = L\frac{\lambda_0}{\mu_0}T \qquad (4.2)$$

so linear depending of the length.

4.1. The sectioning of the place determination from the restriction: $MTTD \leq MTTD_{critic}$

If *MTTD* is limited, for example by an agreement to the value $MTTD_K$, the first measure that the distribution company can take is the place of a disconnector of sectioning, at distance from the source.

$$L\frac{\lambda_0}{\mu_0}T \leq MTTD_K \quad \Rightarrow \quad L \leq MTTD_K \cdot \frac{\mu_0}{\lambda_0 T} \qquad (4.3)$$

4.2 The sectioning of the place determination from the proportion cost/benefit

The undelivered total energy because of the defects from the area *1*, unsectioned, will be:

$$W_{n1} = MTTD_1 \cdot \sum_{1}^{3} L_i \tag{4.4}$$

If we section the area *1,* to the distance L_1' and we accept the uniform distribution of C_1 on L_1:

$$W_{n1}' = MTTD_1 \cdot \frac{L_1'}{L_1} \cdot \left[C_1 \frac{L_1 - L_1'}{L_1} + C_2 + C_3 \right] \tag{4.5}$$

that L'_1 result from the inequality:

$$K_S < W_{n1}' \cdot K_0$$

K_S – expenses for sectioning;
K_0 – cost of the undelivered energy unity.

5. THE EQUIP OF THE NETWORK BUS OPTIMIZATION

Considering a bus network, like that from figure 5.1, we will write under table form (table 5.1), the terms of the minimizing function *Z*, for different buss. In the first column of the table we present the predicted device, in the third the growth corresponding to the investment, in the fifth the growth of Z_{av} because of the error probability of the introduced device and in the last one Z_{cal}.

$$Z=(p+p_a)\cdot I+Z_{av}+Z_{cal} \tag{5.1}$$

Table 5.1

	Terms					
Equipment		I	ΔI	Z_{av}	ΔZ_{av}	Z_{cal}
	0	I_0	—	$f_1 \cdot r \cdot d_1 + f_1 \cdot r \cdot d_2 + f_2 \cdot r \cdot d_1 + f_2 \cdot r \cdot d_2 + f_3 \cdot r \cdot d_1 + f_3 \cdot r \cdot d_2$	c	—
	S_1	I_0	I_S	$f_1 \cdot r \cdot d_1 + f_1 \cdot c_S \cdot d_2 + f_2 \cdot r \cdot d_1 + f_2 \cdot r \cdot d_2 + f_3 \cdot r \cdot d_1 + f_3 \cdot r \cdot d_2$	$f_s \cdot r_s \cdot (d_1+d_2)$	—
	S_2	I_0	I_S	$f_1 \cdot r \cdot d_1 + f_1 \cdot r \cdot d_2 + f_2 \cdot c_S \cdot d_1 + f_2 \cdot r \cdot d_2 + f_3 \cdot r \cdot d_1 + f_3 \cdot r \cdot d_2$	$f_s \cdot r_s \cdot (d_1+d_2)$	—
	$S_1 + S_2$	I_0	$2I_S$	$f_1 \cdot r \cdot d_1 + f_1 \cdot c_S \cdot d_2 + f_2 \cdot c_S \cdot d_1 + f_2 \cdot r \cdot d_2 + f_3 \cdot r \cdot d_1 + f_3 \cdot r \cdot d_2$	$2 \cdot f_s \cdot r_s \cdot (d_1+d_2)$	—
	I_1	I_0	I_{c1}	$f_1 \cdot r \cdot d_1 + 0 + f_2 \cdot r \cdot d_1 + f_2 \cdot r \cdot d_2 + f_3 \cdot r \cdot d_1 + f_3 \cdot r \cdot d_2$	$f_s \cdot r_s \cdot (d_1+d_2) + f_{î} \cdot c_S \cdot d_2 + f_{î} \cdot r_{î} \cdot d_1$	$f_1 \cdot c \cdot \delta_2$
	I_2	I_0	I_{c2}	$f_1 \cdot r \cdot d_1 + f_1 \cdot r \cdot d_2 + 0 + f_2 \cdot r \cdot d_2 + f_3 \cdot r \cdot d_1 + f_3 \cdot r \cdot d_2$	$f_s \cdot r_s \cdot (d_1+d_2) + f_{î} \cdot c_S \cdot d_1 + f_{î} \cdot r_{î} \cdot d_2$	$f_1 \cdot c \cdot \delta_1$
	$I_1 + I_2$	I_0	$I_{c1} + I_{c2}$	$f_1 \cdot r \cdot d_1 + 0 + 0 + f_2 \cdot r \cdot d_2 + f_3 \cdot r \cdot d_1 + f_3 \cdot r \cdot d_2$	$2 \cdot f_s \cdot r_s \cdot (d_1+d_2) + f_{î} \cdot c_S \cdot (d1+d2) + f_{î} \cdot r_{î} \cdot (d_1+d_2)$	$f_1 \cdot c \cdot \delta_1 + f_1 \cdot c \cdot \delta_2$

To the making up of the table we used next notes:

- f_i – the mean probable frequency of appearance of the damage in the *i* area of the network;
- r – mean time of fixed the damage:
- c_s – mean time to disconnected a disconnector and connect a switcher, started uptown;
- c – mean time to start a switcher;
- f_s – mean frequency to damage a disconnector;
- $f_{î}$ - mean frequency to damage a switcher;
- r_s – mean time to improve a damage to the disconnector.

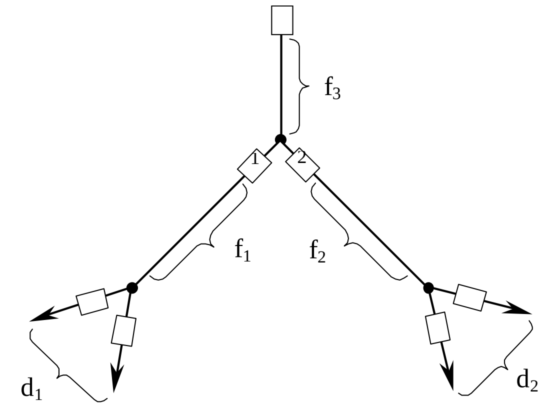

Figure 5.1 Analyzed bus network

Analyzing the table 4.1 results that in the point I_1 from figure 5.1 we will fit up a switcher if the next inequality is satisfied:

$$f_1 \cdot r \cdot d_2 - f_s \cdot r_s \cdot (d_1 + d_2) - f_{\hat{\imath}} \cdot c_s \cdot r_{\hat{\imath}} \cdot d_2 \cdot d_1 - f_{\hat{\imath}} \cdot c \ \cdot \delta_2 \geq \ \geq S + (p + p_a) \cdot I_c \tag{5.2}$$

which we will put under the form $A \geq B$, or we will fit up a disconnector if the next inequality is satisfied:

$$f_1 \cdot r \cdot d_2 - f_1 \cdot c_s \cdot d_2 - f_s \cdot r_s \cdot (d_2 + d_1) \geq S + (p + p_a) + I \tag{5.3}$$

which we will put under the form: $C \geq D$, where:
S – the minimum to start a supplementary investment;
I_C – the cost of the investment for a switcher cell;
I_S – the cost of the investment for a disconnector cell;
f_1, f_2, d_1, d_2 – correspond to the notes from fig. 5.1.
Based on the previous reasoning we can formulate an algorithm to determine the optimal equip of a radial network, an algorithm presented in figure 5.2 and 5.3.
An example for how is applied the method is presented for a simple distribution network, whiles for a complex distribution network, the method leads to an increase unreasonable of the papers volume.

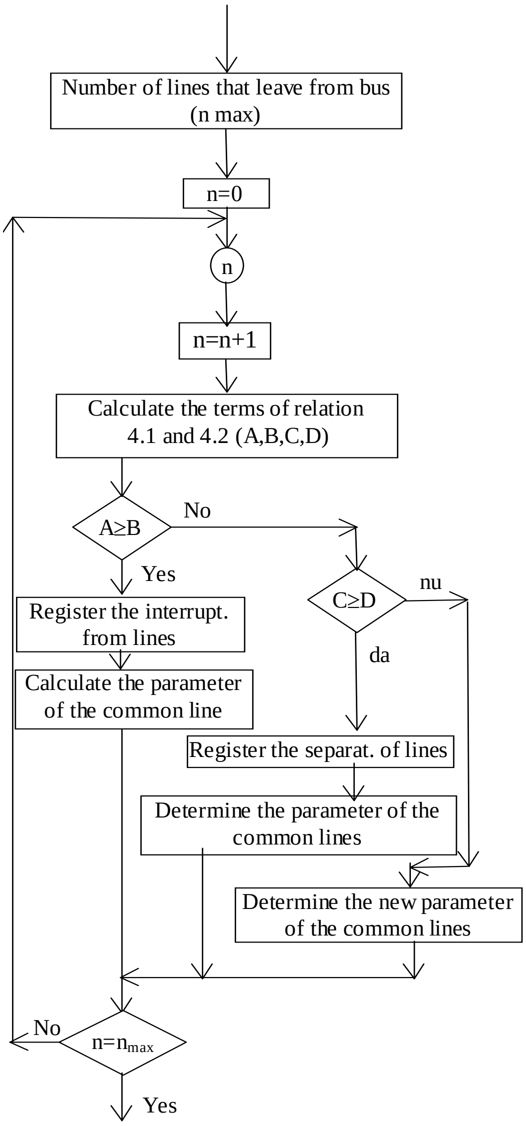

Figure 5.2 Procedure CSP

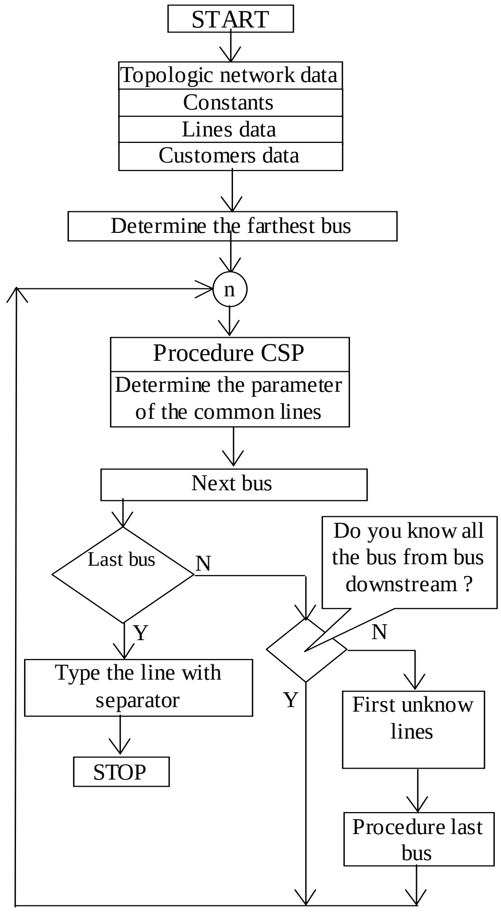

Figure 5.3 Algorithm to optimal equip of a network

6. CONCLUSIONS

In this moment the authors don't know the objective criterions for estimate of the distribution networks, but is presented few punctual criterions for optimal development and exploitation network. The criterion of the statistical selectivity and sensitivity, proposed by the authors, can stay to the base of development and of the exploitation of the distribution network, which in our country, especially in the rural environment, have a reduced selectivity. The authors propose relationship and algorithm, which can lead to the optimization of the corrective maintenance operation and of the development of these networks, having at the base the proposed criterion. A support for proposed methods are the conclusion from bibliography [1] that presents the partial aspects of problems.

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