OPTIMIZATION OF RELIABILITY ELECTRIC POWER TRANSMISSION AND DISTRIBUTION NETWORKS

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ABSTRACT

The problem of quality services provided by suppliers of electricity is currently a major problem due to significant economic implications given the complexity and cost of electric power transmission and distribution systems on the one hand and consumers on the other side who are becoming more demanding in regarding the quality of electricity supplied. Starting from this real situation, the paper develops nonlinear mathematical model of optimization of reliability through redundancy, knowing that according to literature, redundancy helps to increase system reliability.

Keywords: power quality, reliability, redundancy, optimization, MATLab 6.5 application

1. Introduction

The mathematical model of reliability through redundancy optimization has been applied for overhead power line Ungheni - Raciu, county Mures, Romania, in the next hypothesis and conditions:

1. Damages impose by the time of non functioning of electric power distribution network;
2. Damages impose by the number of unplanned interruption of electric power distribution network.

Considering the fact that the parallel type structure is completely redundant, the optimization of redundancy refers in the first place to the serial structure systems.

The modeling and optimization quality of energy supply to consumers generates in terms of mathematics, nonlinear programming models, through the criterion function and/or imposed restrictions on the vector of optimized variables.

2. Case study 1

Hypothesis: Damages imposed by the time of non functioning of electric power distribution network

The overhead power line Ungheni - Raciu, county Mures, Romania, is achieved thought the scheme shown in Figure 1.

The electrical parameters of consumer are:

- average power required of consumer is Pc = 2.5 [MW];
- operating planned during ten years, id Tp = 87600 hours.

Let establish the optimum level of redundancy of elements radial system shown in Figure 1, in conditions of some damages imposed by consumer (VDmax), damages due to the non functioning of a electric power supply and with a specific damage $d_\beta = 10000$ euro/MWh undelivered.

3. Structure of mathematical model

Variable to be optimized are the number of identical items in reserve for each element of the scheme, or:

$$X = [x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ x_{11}\ x_{12}] \quad (1)$$

Criterion function to optimize the model is determined by minimizing the cost of elements (equipment). In the study:

$$\min\{C(x)\} \quad (2)$$

$$C(X) = \sum_{\substack{i=1,12 \\ i\neq 5}} X_i \cdot I_i + X_5 \cdot \alpha_5 \cdot L$$

Where: c_i are specific costs [euro/piece] and they having hypothetical values because the cost of equipments and electric lines varies depending on the manufacturer (performer), to admit their expression [euro] (currency units).

The model restrictions are imposed by two conditions:

a. The construction, under which the number of items in the reserve for each equipment E_i will be:

$$1 \le X_i \le 3 \,\big|\, i = 1,12 \quad (3)$$

b. Economics impose by condition that the damages at the consumer do not exceed a date value (VDmax) owing to the interruption time at a power supply, or:

$$P_c \cdot d_\beta \cdot Q(X) \cdot T_h \le VD\max \quad (4)$$

The model thus formulated was solved using the MATlab programming environment.

4. Results

In Table 1, initial values were calculated for variant non optimized of system.

Optimal values were calculated for variants optimized of redundancy elements presented in Table 1, through running the optimization for different values of damages caused by non functioning time at a supply power (VDmax), the value is imposed by the consumer to the supplier of energy.

From the analysis of Table 1 is a noticeable increase in the number of redundant components, with the decline in value of the damage required (VD max) or with increasing specific damages.

Table 1. The reliability study of overhead power line Ungheni – Raciu, $d_{\beta} = 10000$ **euro/MWh undelivered**

PARAMETERS		EXISTING	OPTIMIZED				
1. Damage value accepted **VD max** [thousands EURO]		60831	10000	5000	1000	100	10
2. Probability of success **P**		0.97222	0.9954	0.9977	0.9995	0.99995	0.99999
3. Total medium time of refuse **MrTp** [h]		2433.241	400.00	200.00	40.00	4.00	0.40
4. Medium number of interruption **MyTp** [pieces]		32.15	6.812	3.838	0.922	0.114	0.013
5. INVESTMENT VALUE [thousands EURO]		341.58	420.38	445.02	592.43	740.12	887.80
STATION UNGHENI 220/110 Kv CELL 110 kV	1	2	2	2	2	2	2
IO – 110 kV	2	1	1.48	1.62	1.94	2.39	2.84
CESU – 110 kV	3	1	1.12	1.19	1.35	1.58	1.81
STEP 110 kV	4	1	1	1.00	1.16	1.39	1.62
OPL – 110 kV 3 x 185 28 km	5	1	1.23	1.37	1.68	2.12	2.56
STEP 110 kV	6	1	1	1.00	1.16	1.39	1.62
IUP – 110 kV	7	1	1.48	1.62	1.94	2.39	2.84
CESU – 110 kV	8	1	1.12	1.19	1.35	1.58	1.81
TRANSFORMER 110/20 kV 10 MVA	9	1	1.33	1.48	1.82	2.30	2.78
RC – 20 kV	10	1	1.14	1.21	1.35	1.56	1.77
IO – 20 Kv	11	1	1.51	1.62	1.87	2.33	2.59
STATION 110/20 kV RACIU	12	1	1.1	1.16	1.31	1.52	1.74

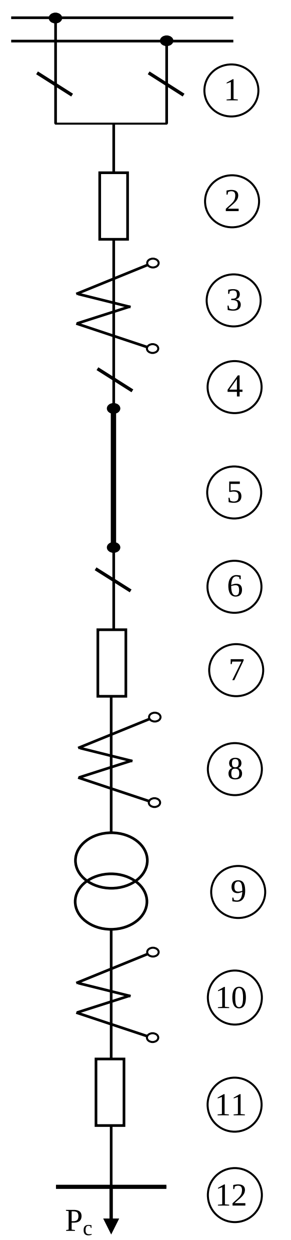

Fig. 1 – Overhead power line Ungheni – Raciu

5. Case study 2

Hypothesis: Damages imposed by the number of

unplanned interruption of the electric power distribution network

Currently the Raciu Station 110/20 kV is supplied from the 220/110 kV Ungheni Station through overhead power line 110 kV. The overhead power line has a length of 28 kilometers and she has a transformer of 10 MVA according to the scheme presented in Figure 2. In the absence of reliability parameters of existing electrical appliances it was adopted from the NTE 005/06 regulations, the following parameters of equipment and 110 kV line and have been assessed costs:

Table 2. Reliability parameters

Intensity of damage $\lambda\ [s^{-1}]$	Intensity of repair $\mu\ [s^{-1}]$	COST [thousands EURO]
$\lambda_1 = 0.3827777 \cdot 10^{-8}$	$\mu_1 = 1622.783 \cdot 10^{-8}$	13,0
$\lambda_2 = 2.955555 \cdot 10^{-8}$	$\mu_2 = 478.8405 \cdot 10^{-8}$	36,0
$\lambda_3 = 0.01666666 \cdot 10^{-8}$	$\mu_3 = 416.6666 \cdot 10^{-8}$	1,5
$\lambda_4 = 0.05944444 \cdot 10^{-8}$	$\mu_4 = 1430.555 \cdot 10^{-8}$	11,0
$\lambda_5 = 2.465555 \cdot 10^{-8}$	$\mu_5 = 450 \cdot 10^{-8}$	115,08
$\lambda_5 = 2.465555 \cdot 10^{-8}$	$\mu_6 = 1430.555 \cdot 10^{-8}$	11,0
$\lambda_7 = 2.955555 \cdot 10^{-8}$	$\mu_7 = 478.8405 \cdot 10^{-8}$	36,0
$\lambda_8 = 0.01666666 \cdot 10^{-8}$	$\mu_8 = 416.6666 \cdot 10^{-8}$	1,5
$\lambda_9 = 0.5833333 \cdot 10^{-8}$	$\mu_9 = 69.44444 \cdot 10^{-8}$	110
$\lambda_{10} = 0.025 \cdot 10^{-8}$	$\mu_{10} = 1527.777 \cdot 10^{-8}$	0,5
$\lambda_{11} = 0.8888888 \cdot 10^{-8}$	$\mu_{11} = 555.5555 \cdot 10^{-8}$	5,0

The electric supply of overhead power line Ungheni-Raciu, county Mures, Romania, is achieved thought the scheme shown in Figure 2.

The electrical parameters of consumer are:

- average power required of consumer is Pc = 2.5 [MW];
- operating planned during ten years, id Tp = 87600 hours.

The reliability parameters of equipments and 110 kV overhead power line are presented in Table 2.

Let establish the optimum level of redundancy of elements radial system shown in Figure 2, in conditions of some damages impose by consumer, damages due by the number of unplanned interruption of the electric power distribution network and with a specific damage $d_\upsilon = 10000$ euro/interruption.

6. Structure of mathematical model

Variable to be optimized are the number of identical items in reserve for each element of the scheme, or:

$$X = [x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ x_{11}\ x_{12}] \quad (5)$$

Criterion function to optimize the model is determined by minimizing the cost elements (equipment). In the study:

$$\min\{C(x)\} \quad (6)$$

$$C(X) = \sum_{\substack{i=1,12 \\ i \neq 5}} X_i \cdot I_i + X_5 \cdot \alpha_5 \cdot L$$

Where: c_i are specific costs [euro/piece] and they having hypothetical values because the cost of equipments and electric lines varies depending on the manufacturer (performer), to admit their expression [euro] (currency units).

The model restrictions are imposed by two conditions:

a. The construction, under which the number of items in the reserve for each equipment E_i will be:

$$1 \le X_i \le 3 \mid i = 1{,}12 \quad (7)$$

b. Economics impose by condition that the damages at the consumer do not exceed a date value (VD^N) owing by the number of unplanned interruption of electric power distribution network during $T_s = T_h \cdot 3600$ [seconds], or:

$$d_\upsilon \cdot \lambda_E(X) \cdot P(X) \cdot T_s \le VD^N \quad (8)$$

The model thus formulated was solved using the MATLAB programming environment and was included on the file OPTRED4.

The file OPTRED4 contains the next programs:

- \ objfun A4.m – for objective function;
- \ mat A4.m – for formation linear constraints and for run the optimization function *fmincon*;
- \ restr A4.m – for formation nonlinear constraints and for introduction the initials dates of identify the system;
- \ optim A4.m – in order to calculate he display the results, in different variants of study.

7. Results

In Table 3, initial values were calculated for non optimized variant of system.

Optimal values were calculated for variants optimized of redundancy elements presented in Table 3, through running the optimization for different values of damage caused by the number of unplanned interruption of electric power distribution network and with a specific damage $d_\upsilon = 10000$ euro/interruption.

From the analysis of Table 3 is a noticeable increase in the number of redundant components, with the decline in value of the damages imposed, or along with the growth of specific damages.

Table 3. The reliability study of overhead power line Ungheni – Raciu, $d_{\upsilon} = 10000$ **Euro/interruption.**

PARAMETERS	EXISTING	OPTIMIZED			
1. The unit amount of the damages **dn = 10** [thousands EURO/interruption]	-	10	10	10	10
2. Damage value accepted **VDmax** [thousands EURO]	-	100	50	10	1
3. Probability of success **P**	0.97222	0,98718	0.99019	0.99853	0.99989
4. Total medium time of refuse **MrTp** [h]	2433.241	1122.977	858.664	128.694	9.199
5. Medium number of interruption **MyTp** [pieces/10 years]	32.015	10.000	5.000	1.000	0.100
6. INVESTMENT VALUE [thousands EURO]	341.58	402.04	445.74	563.15	724.60
7. Number of equipment	pieces	pieces	pieces	pieces	pieces
STATION UNGHENI 220/110 Kv CELULA 110 kV	2	2	2	2	2
IO – 110 kV	1	1.433	1.647	2.007	2.501
CESU – 110 kV	1	1,064	1.165	1.340	1.582
STEP 110 kV	1	1	1.087	1.263	1.507
LEA – 110 kV 3 x 185 28 km	1	1.114	1.333	1.695	2.186
STEP 110 kV	1	1	1.087	1.263	1.507
IUP – 110 kV	1	1.433	1.647	2.007	2.501
CESU – 110 kV	1	1.064	1.165	1.340	1.582
TRANSFORMER 110/20 kV 10 MVA	1	1	1	1.397	1.953
RC – 20 kV	1	1.217	1.308	1.466	1.686
IO – 20 Kv	1	1.514	1.676	1.952	2.335
STATION 110/20 kV RACIU	1	1.179	1.272	1.433	1.658

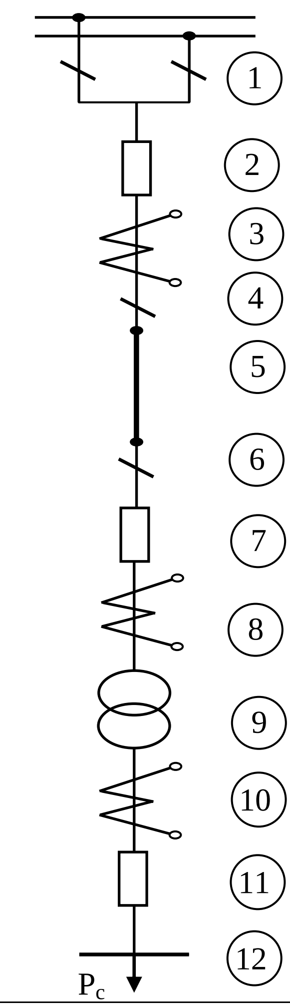

Fig. 2 – Overhead power line Ungheni – Raciu

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