OPTIMIZATION OF THE ELECTRICITY SUPPLY SCHEME FOR THE INDUSTRIAL CONSUMERS

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INTRODUCTION

Electricity supply system of the industrial consumer (figure 1) is composed by the external system and by the inside system. The zone network

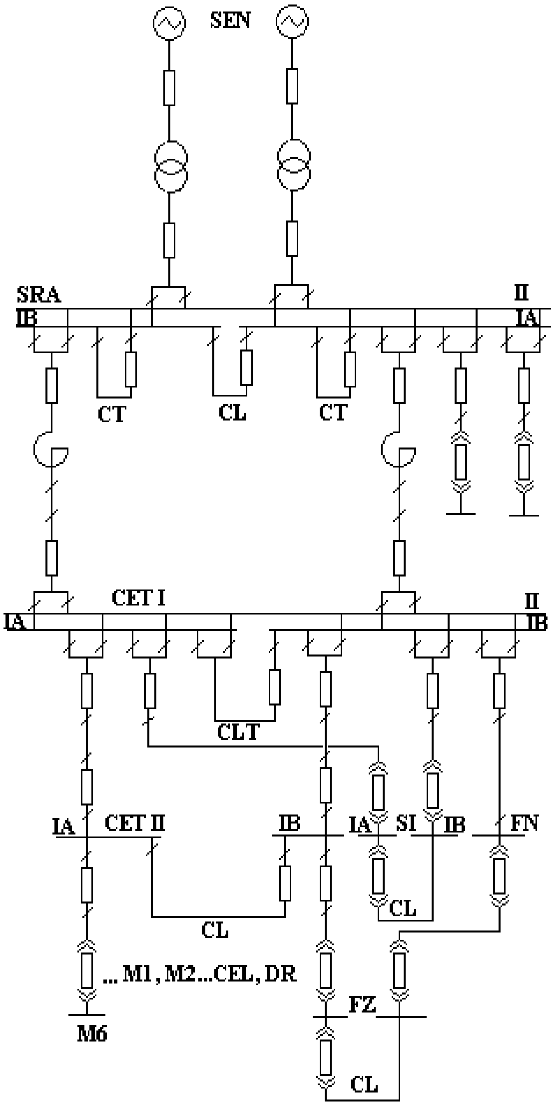

Figure 1. Supply scheme for medium voltage

of the National Energy System (SEN) gives the external system. The electricity receiving substations, the inside distribution networks and the electricity own sources give inside system of the company.

In case of the important consumed power, the main transformer substations type SRA supplies company. This substation transforms electricity from SEN voltage to industrial network voltage.

The medium and low voltage feeders and unit substations compose inside distribution network.

Working normal scheme of medium voltage distribution network, type radial, with more steps is shown in Figure. This is distribution scheme of company. The big number of steps and adjustment values of protections that are imposed by the external network determine reducing of difference between steps down 0.4 s. Thus, due to working time dispersion of time relays and of maximal relays and of circuit-breakers, working of protections is unselective. For that, it is necessary change of steps number. This is made so:

- supply of some vital consumers from SRA directly;
- change of working scheme and take out some protections. This is made taking account to influence about working of whole company.

1. FORMULATION OF OPTIMIZATION PROBLEM

The optimization problem is follow:

- the objective function:

$$D_{i,k} = \min! \ ,$$

i=1...3 variants; k=1...15 installations; (1)

- constrains:

$$n_{tr} < n_{SRA} / 0{,}4 \qquad (2)$$

$$I_{\max,l} < I_{\max\,adm,l}\ ,\ \ l = 1...n_1 \qquad (3)$$

$$Sk_j < Sr\,\mathrm{int}\ r_j\ ,\ \ j = 1...n_{intr} \qquad (4)$$

where: $D_{i,k}$ – damages caused by the stopping of installations for one of variants analyzed; n_{tr} – steps number of current maximal protection; t_{SRA}- maxim time step received by the maximal protection of transformer in SRA; $I_{max,l}$, $I_{max\ adm,l}$ – feeders currents existing and received, respectively; n_1 – feeders number; Sk_j , Sr int r_j – short-circuit power and breaking power of circuit-breaker j; n_{intr} – circuit-breakers number.

2. THE CONSTRAINS OF THE OPTIMIZATION PROBLEM

With a view to increase of reliability it is considered situations that do not require new investments.

It is imposed following constrains:

1) time difference between two steps successively must be up or equal 0.4s;
2) short-circuit currents in the scheme changed must be down breaking capacity of circuit-breakers existing;
3) short-circuit currents in the scheme changed must be down rated thermal current of cables/lines.

For scheme in figure 1, after calculus, it is founded that constrains 2 and 3 are carry out for all variants analysed. These variants are:

- variant 1 – longitudinal couple (CL) in substation FZ is open, longitudinal couple in substation CET II is open, busbar IA and IB being supply separately;
- variant 2 – longitudinal couple (CL) in substation FZ is open, longitudinal couple in substation CET I is open, busbar IA and IB being supply separately;
- variant 3 – substations CET I, M11 and M12 are supply from SRA, busbar II.

3. THE OBJECTIVE FUNCTION OF THE OPTIMIZATION PROBLEM

Damages caused by the stopping of installations are calculated using following relation:

$$D_k = (t_{rp} + t)\cdot d_h + \lfloor t_1 \cdot ee_1 + (t_{rp} - t_1)\cdot ee_2 \rfloor \cdot pee + t_{rp} \cdot et \cdot pet \quad , \qquad ([\$/year]) \tag{5}$$

where: t_{rp} – starting time again, in h; t – stopping time, in h; t_1 – starting time again, in h, when electric energy losses are ee₁, in *kWh/h*; ee_2 – electric energy losses in time (t_{rp}-t_1), in *kWh/h*; *et* – thermal energy losses, in *kJ/h*; *pee*, *pet* – price of electric energy, in *\$/kWh*, and price of thermal energy, in *\$/kJ*;

$$d_h = (PR_h - CM_h)\cdot PR_h \,, \quad [\$/h]; \tag{6}$$

where: d_h – damages per hour, in *\$/h*; PR_h - value of production per hour, in *\$/h*; CM_h – costs with raw materials per hour, in *\$/h* .

Damages d_h are considered constant. Starting time again, t_{rp}, is depending on stop time.

4. CALCULATION OF RELIABILITY INDICES

For calculation of damages (relation 5) it is necessary to know stopping time, t. This is depending on reliability indices. These indices are calculated for a reference duration T=1 *year* (8760 *h*), using reducing proceeding of calculation scheme by equalization.

Presence of voltage at bus bar of consumers is considered success state.

The reliability equivalent of series with n elements is calculated as:

$$\lambda_e = \sum_{i=1}^{n} \lambda_i \,, \quad [h]; \tag{7}$$

$$\mu_e = \frac{\lambda_e}{\sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}} \,, \quad [h] \tag{8}$$

and for two elements in parallel:

$$\lambda_e = \frac{\lambda_1 \cdot \lambda_2 \cdot (\mu_1 + \mu_2)}{\mu_1 \cdot \mu_2 + \lambda_1 \cdot \mu_2 + \lambda_2 \cdot \mu_1} \,, \quad [h]; \tag{9}$$

$$\mu_e = \mu_1 + \mu_2 \,, \quad [h]. \tag{10}$$

The success probability of element equivalent to all equipments of supply way:

$$P_1 = \frac{\mu_{e,1}}{\mu_{e,1} + \lambda_{e,1}} \,. \tag{11}$$

The refuse probability of element equivalent to equipments unreserved (that come back to the success state by repairs):

$$P_r = \frac{\lambda_{e,1}}{\lambda_{e,1} + \mu_{e,1}} . \quad (12)$$

The success probability of element equivalent to equipments unreserved:

$$P_s = 1 - P_r . \quad (13)$$

Failure rate of element equivalent to equipments (that come back to the success state by manual switches):

$$\lambda_{e,2} = \lambda_e - \lambda_{e1} . \quad (14)$$

Yearly mean number of unsuccess states (breaks) removed by repairs:

$$N_i = P_s \cdot \lambda_{e,1} \cdot T , \qquad T = 8760\ h. \quad (15)$$

Yearly mean number of unsuccess states (switches) removed by manual switches:

$$N_{man} = P_1 \cdot \lambda_{e,2} \cdot T . \quad (16)$$

Total mean duration of breaks removed by repairs:

$$T_i = P_r \cdot T , \qquad [h/year]. \quad (17)$$

Total mean duration of switches:

$$T_{man} = t_{man} \cdot N_{man}, \qquad [h/year], \quad (18)$$

where t_{man} is time necessary for one switch that is determined based working experience.

Mean duration of one break removed by repairs:

$$tp_i = \frac{T_i}{N_i}, \qquad [h/break]. \quad (19)$$

Damages for every variant analyzed are determined as:

$$D_i = \sum_{k=1}^{15} D_{i,k} , \qquad [\$/year], \quad (20)$$

where $D_{i,k}$ – damages for installation k in variant i.

5. NUMERICAL RESULTS

The optimization algorithm presented up was applied in a company that has normal working scheme in figure 1. Damages of every consumer and of whole company for every variant are shown in table 1. It is seen that variant 2 is optimal variant. For this variant, damages of whole company are minimum. If normal supply scheme is as variant 2, can be obtained minimum savings by 689 *$/year* and maximum savings by 6180 *$/year*.

Table 1. Yearly damages.

Installation	Yearly damages, [$/year]		
	Variant 1	Variant 2	Variant 3
M1	67	65	61
M2	201	194	183
M3	49	51	44
M4	134	130	122
M5	219	222	211
M6	874	886	841
M7	747	759	713
M8	230	239	205
M9	84	82	78
M10	87	95	80
M11	7626	7624	7516
M12	222	224	145
CEL	3417	3286	3000
DR	163	160	110
CET	29464	28869	35767
Whole company	43585	42896	49076

CONCLUSIONS

Reliability of electricity supply system of industrial consumers has important economical implications.

The accidental breaks have frequencies and duration that depending on the safety level ensured by SEN, by supply scheme and by the equipments quality.

Using optimization algorithm presented in this paper, it can be minimize damages caused by the unsupply consumers by selection of working scheme, without investments.

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