ANALYSIS OF THERMIC STABILITY IN SHORT CIRCUIT REGIME OF ELECTRIC DISTRIBUTION NETWORKS CONDUCTOR

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ABSTRACT: In this paper is presented in detail the analytical model of calculus in restraint of analysis of thermic stability in short circuit regime of electric distribution networks conductor using the Matlab program. In first part of this paper after a short introduction is presented the mathematic model after that in the second part is presented the simulation results in the case of electric air line and the electric cables. In final are presented the principal conclusions.

KEY WORDS: *thermic stability, electric, short circuit, network*

1. INTRODUCTION

The short circuit currents produce thermic effects and mechanical stress (inflexion, extent, compressing) in the current ways whom cross.

Therefore is necessary the check up thermic stability at various moments of time of the moment short circuit appearance and controlling shock current at dynamic stability. At thermic stability is checked up both rigid current ways as the flexible ways.

The aim has controlling chosen section (s) in short circuit conditions, with relation:

$$s \geq s_t \tag{1}$$

where:

s_t is the minimum section thermic assessed , in terms of mm^2

In such of situations can be controlled the maximum value of temperature which would attain the conductor, θ_k, at transition the short circuit current, a certain period of time, with relation:

$$\theta_k \leq \theta_{k\,max} \tag{2}$$

where:

$\theta_{k\,max}$ represents the maximum temperature of conductor at disconnection short circuit, in term of °C and which the head line conductor is:

- From aluminum: 180 °C
- From cooper and steel: 200 °C

2. ANALYTICAL MODEL ATTENDANCE

Checking the thermic stability at short circuit of electric line conductors, according to PE 103/92 prescription, is obligatory in case of all those overhead and cable lines, and in case of overhead lines are necessary at networks with 110 kV tensions or more.

If take into consideration the duration very small of the short circuit current, heating the electric line conductors in this mode of operation are considered an adiabatic process.

In this assumption, the conductor section crossed of a short circuit current i(t), whereon after the time t is attained the maximum temperature admissible θ_{max}, is given by the following equation:

$$s_k = I_{km} \cdot t^{\frac{1}{2}} \cdot \left[R(\theta_{max}) - R(\theta_i)\right]^{-\frac{1}{2}} = = I_{km} \cdot \sqrt{\frac{t}{R(\theta_{max}) - R(\theta_i)}} \tag{3}$$

In equation mentioned above, the thermic rigidity $R(\theta)$ is a function which depends of material constant and the temperature of conductor:

$$R(\theta_{max}) - R(\theta_i) = \int_0^{\theta_{max}} \frac{c_m(\theta) \cdot \gamma}{\rho(\theta)} \cdot d\theta \tag{4}$$

where:

θ_i is initial conductor temperature, in terms of °C

θ_{max} maximum admissible temperature conductor, in terms of °C

c_m heat capacity the material conductor, in terms of kcal/N°C

γ bulk density of material conductor, in terms of N/dm^3

ρ conductor material resistivity, in terms of $\Omega mm^2/m$

In technical literature are presented more than methods of to calculus this function (the V.D.E method, the fictive time method, thermic rigidity methods) [1, 2, 3].

The method used frequent in our country consider: c_m=constant, again $\rho(\theta) = \rho \cdot (1 + \alpha_o \cdot \theta)$, what lead on in conclusive, at analytically expression:

$$[R(\theta_{max}) - R(\theta_i)]^{-\frac{1}{2}} = \left[\frac{c_m \cdot \gamma}{\alpha_0 \cdot \rho_{20}} \cdot (1 + 20 \cdot \alpha_0)\right]^{-\frac{1}{2}} \cdot \left[\ln \frac{1 + \alpha_0 \cdot \theta_{max}}{1 + \alpha_0 \cdot \theta_i}\right]^{-\frac{1}{2}} = A_1 \cdot A_2 \quad (5)$$

which can lay under the following form:

$$\frac{1}{\sqrt{R(\theta_{max}) - R(\theta_i)}} = \frac{1}{\sqrt{\frac{c_m \cdot \gamma}{\alpha_0 \cdot \rho_{20}} \cdot (1 + 20 \cdot \alpha_0)}} \cdot \frac{1}{\sqrt{\ln \frac{1 + \alpha_0 \cdot \theta_{max}}{1 + \alpha_0 \cdot \theta_i}}} = A_1 \cdot A_2 \quad (6)$$

In analytical expressions aforesaid is notation with:

$$A_1 = \left[\frac{c_m \cdot \gamma}{\alpha_0 \cdot \rho_{20}} \cdot (1 + 20 \cdot \alpha_0)\right]^{-\frac{1}{2}} = \frac{1}{\sqrt{\frac{c_m \cdot \gamma}{\alpha_0 \cdot \rho_{20}} \cdot (1 + 20 \cdot \alpha_0)}} \quad (7)$$

$$A_2 = \left[\ln \frac{1 + \alpha_0 \cdot \theta_{max}}{1 + \alpha_0 \cdot \theta_i}\right]^{-\frac{1}{2}} = \frac{1}{\sqrt{\ln \frac{1 + \alpha_0 \cdot \theta_{max}}{1 + \alpha_0 \cdot \theta_i}}} \quad (8)$$

The quadratic mean value off short circuit current I_{kn}, in terms of kA, is given by equation:

$$I_{km}^2 = \frac{1}{t} \cdot \int_0^t i^2(t)dt \quad (9)$$

With a view to determine the short circuit current, I_{kn}, is used the following approximately equation:

$$I_{km} = I_{k0} \cdot (m + n)^{\frac{1}{2}} = I_{k0} \cdot \sqrt{m + n} \quad (10)$$

in which:

I_{k0} is the effective initial value of periodic short circuit current component, in terms of kA

m the coefficient corresponding affect aperiodic component of short circuit current at the heating conductor, given by equation:

$$m = \frac{T_a}{t} \cdot \left[1 - \exp\left(-\frac{2 \cdot t}{T_a}\right)\right] \quad (11)$$

where:

T_a is the constant time off circuit. In case off electric distribution networks can be considered the his value $T_a = 0.045\,s$.

t short circuit duration, in terms of s

n coefficient for which take into account of variation influence in time off periodic component on heating off conductor; in case of short circuits alimentation of an infinite power system $(U = \text{constant}; S \to \infty)$, arise that $n = 1$.

The relation of calculus for conductor section crossed by a short circuit current is:

$$s_k = A_1 \cdot A_2 \cdot I_{km} \cdot \sqrt{t} = A_1 \cdot A_2 \cdot I_{k0} \cdot [t \cdot (m + n)]^{\frac{1}{2}} = A_1 \cdot A_2 \cdot I_{k0} \cdot \sqrt{t(m + n)} \quad (12)$$

Analytical expression of short circuit current at thermic stability in case off overhead electric line conductors and respective in case off electric line cable conductors, alimentation of an infinite power system is

$$I_{k0} = \frac{s_k}{A_1 \cdot A_2 \cdot \sqrt{0.045 \cdot \left[1 - \exp\left(-\frac{2t}{0.045}\right)\right] + t}} \quad (13)$$

In analog manner can be check up the conductor section chosen in short circuit regime. In this case the maximum value admission off section for the short circuit current I_k assessed is determined by means of following equation:

$$s_k = I_{k0} \cdot A_1 \cdot A_2 \cdot \sqrt{0.045 \cdot \left[1 - \exp\left(-\frac{2t}{0.045}\right)\right] + t} \quad (14)$$

Density of current j_k in terms of A/mm^2 assessed in short circuit regime is determined in terms of material conductor character (Cu, Al), of initial temperature θ_i and of maximum temperature received θ_{max} at the short circuit finished [1, 2, 3, 4].

Short circuit current produced thermic and mechanic effects in the current way on which these cross.

Therefore is necessary verification off thermic stability at various moments from the short circuit moment appearance and verification dynamic stability at shock current.

3. SIMULATION RESULTS MEAN THE MATLAB PROGRAME

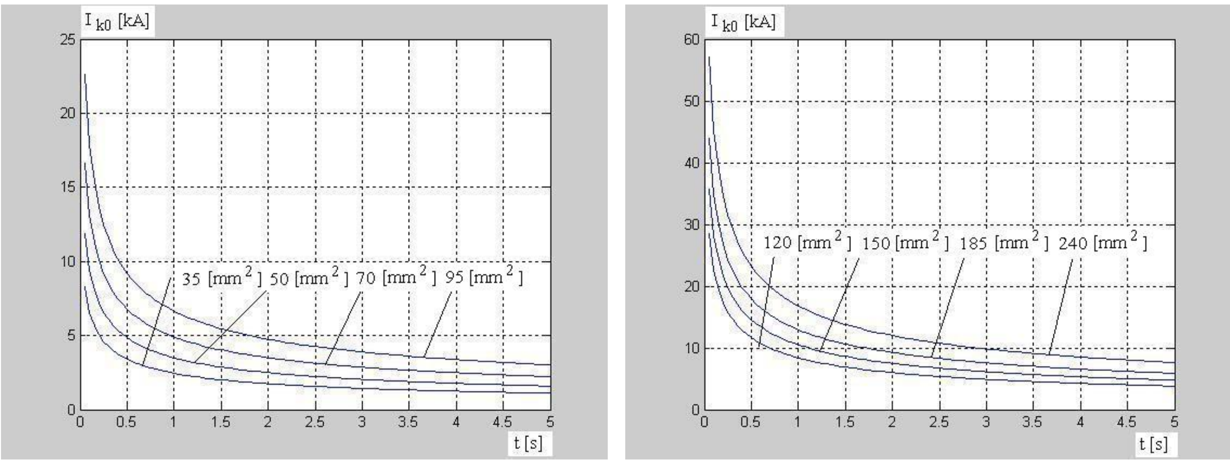
Case study 1

From determining the values of A_1 and A_2, in case of electric head line with aluminum conductors is considered: initial temperature of conductor $\theta_i = 70^\circ C$ and the maximum admissible temperature of conductor $\theta_{max} = 160^\circ C$.

In case of aluminum conductors results the following values: $A_1 = 7.00$ mm²/kA^1/2, and $A_2 = 1.95$. In final is determined the relation from calculus of short circuit currents, in terms of kA, at thermic stability from head line aluminum conductors.

$$I_{k0} = \frac{s_k}{14 \cdot \sqrt{0.045 \cdot \left[1 - \exp\left(-\frac{2t}{0.045}\right)\right] + t}} \quad (15)$$

In figure 1 is presented the results of simulation by through the Matlab program.



a) b)

Figure 1. Short circuit variation corresponding differently standard sections, in terms of fault duration

a) Electric head line with aluminum conductors and sections of: 35, 50, 70, 95 mm²
b) Electric head line with aluminum conductors and sections of: 120, 150, 185, 240 mm²

Case study 2

In the second case from determining the values of A_1 and A_2 from the cables with cooper conductors is adopted the following values: initial temperature of conductor: $\theta_i = 60^\circ C$ and the admissible maximum temperature of conductor $\theta_{max} = 140^\circ C$.

In the case of cooper conductors results in final the following values: $A_1 = 4.65$ mm²/kA^1/2, and $A_2 = 2.05$.

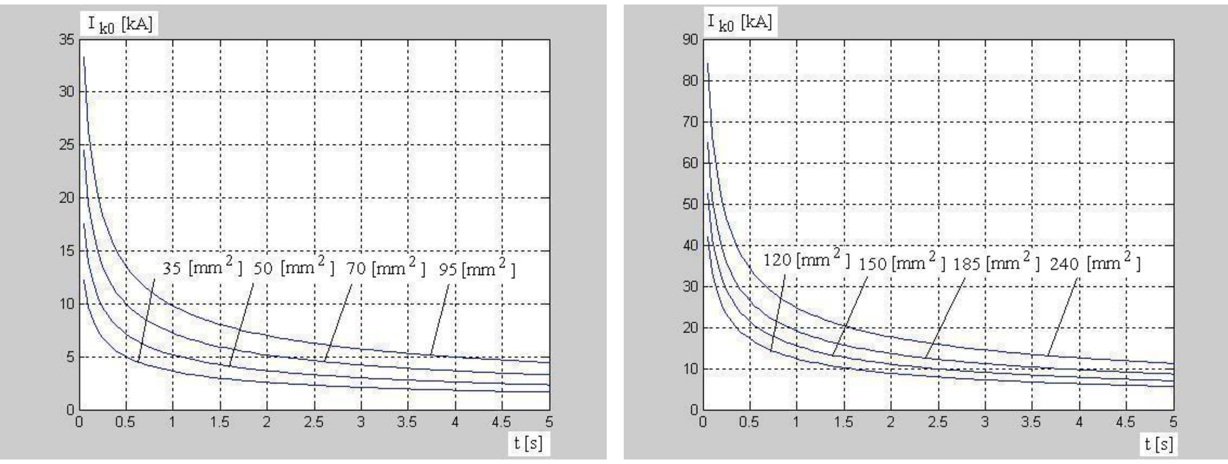
In final is determined the relation of calculus from the short circuit currents at the thermic stability from the cables with cooper conductors.

$$I_{k0} = \frac{s_k}{9.5 \cdot \sqrt{0.045 \cdot \left[1 - \exp\left(-\frac{2t}{0.045}\right)\right] + t}} \quad (16)$$

In table 1, respective in figure 2 is presented the results of simulation by through the Matlab program.

Table 1 Short circuit current values in kA from standard sections the cooper cable in terms of fault time

Section s [mm²]	Fault time t [s]						
	0.05	0.10	0.20	0.50	1.00	1.50	2.00
35	12.28	9.69	7.52	5.05	3.68	2.99	2.59
50	17.54	13.85	10.75	7.21	5.26	4.28	3.70
70	24.56	19.39	15.05	10.10	7.36	5.99	5.18
95	33.33	26.31	20.43	13.70	10	8.13	7.04
120	42.10	33.24	25.80	17.31	12.63	10.27	8.89
150	52.63	41.55	32.25	21.64	15.78	12.84	11.11
185	64.91	51.24	39.78	26.69	19.47	15.83	13.71
240	84.21	66.48	51.61	34.63	25.26	20.54	17.79



a) b)

Figure 2. Short circuit variation corresponding differently standard sections, in terms of fault duration

a) Electric cables with cooper conductors and sections of: 35, 50, 70, 95 mm^2

b) Electric cables with cooper conductors and sections of: 120, 150, 185, 240 mm^2

4. CONCLUSIONS

In conclusion can be mentioned that the values of short circuit in case of electric cables with cooper conductors are more than the values of short circuit currents in case of electric air line with aluminum conductor..

Section necessary for elements leading of current acquire great values alone when the short circuit currents or operating times had great values.

5. REFERENCES

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