Estimation of the Air Power Line Parameters Under the Influence of Lightning Overvoltages

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***Abstract* – The overvoltages in the power systems can't be avoided and is necessary to limit them.**

There is necessity to know of the power line parameters whit positive, negative and zero sequence (R, L and C). They are used when the power line model is constructed. The aim of this paper is estimation of the line parameters in case of direct lightning stroke over the conductor of air power line by using different number of shifted two-dimensional Haar wavelets.

***Keywords* – estimation, air power line parameters, shifted two-dimensional Haar wavelets.**

I. Introduction

The overvoltages in the power systems can't be avoided and is necessary to limit them.

There are three main groups of overvoltages – temporary, switching and lightning overvoltages. Lightning overvoltages originate in atmospheric discharges. A direct lightning stroke causes extremely high overvoltages and thus severe faults.

There is necessity of knowing of power line parameters whit positive and zero sequence (R, L and C). They are used when the power line model is constructed.

The detailed models of line elements are known, but there isn't undivided algorithm for commonly description of power system model.

The algorithm based on non-obvious integration is the most universal and easily applied. Program products are also developed for visual programming – package for modeling of dynamic systems SIMULINK, SCILAB etc. Initiating researching system characteristics occurs in dialogue regime. As a result we get a researching system model. Models parameters don't accord to the catalogue data. This needs previous calculations. This is a small defect.

In the present study the parameters of a power line under the influence of lightning overvoltages are estimated via Haar wavelets technique application.

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II. Mathematical expressions for determination parameters of substitute scheme of air power line in symmetrical coordinates. [2 - 4]

1. Calculation of positive sequence resistance R_1

$$R_1 = \frac{\rho_{20}.\kappa(\omega).\xi(\theta^0).\eta}{S}, \quad \Omega/km \quad (1)$$

where:

ρ_{20} – resistivity of the conductor for 20^0 C, $\Omega.mm^2/km$;

$\kappa(\omega)$ – coefficient, taking into account the change resistance from skin effect;

$$\kappa(\omega) = 1+0,0675.r.\sqrt{\frac{\omega.\mu}{\rho_{20}}} \text{ ,if } r.\sqrt{\frac{\omega.\mu}{\rho_{20}}} \le 4;$$

$$\kappa(\omega) = 1,27+0,401.(r.\sqrt{\frac{\omega.\mu}{\rho_{20}}}-4), \text{ if } r.\sqrt{\frac{\omega.\mu}{\rho_{20}}} > 4;$$

μ – permeability of the conductor, H/m;

ω- radian frequency, rad;

r - radius of the conductor, mm;

$\xi(\theta^0)$ - coefficient, taking into account the change resistance from temperature;

$$\xi(\theta^0) = 1+\alpha.(\theta^o-20^o);$$

α - temperature coefficient of the conductor, $1/^{o}C$;

θ^{o}- work temperature, ^{o}C;

η - coefficient taking into account difference between the real length of the air power line and the conductor length;

$$\eta = 1 + \frac{8}{3}\left(\frac{z}{l_m}\right);$$

z - suspending of the conductor, m; l_m – distance between two poles, m;

S – effective cross – section of the line conductor, mm^2;

2. Calculation of zero sequence resistance R_0

$$R_0 = R_1 + 3.R_3 \qquad (2)$$

R_3 – real ground resistance;

$$R_3 = \frac{\mu_0.\omega}{8}, \Omega / km; \quad \mu_0 = 4\pi.10^{-4}, H / km;$$
$$\omega = 2\pi.f$$

f – frequency , Hz.

3. Calculation of positive sequence inductance L_1

$$L_1 = \frac{\mu_0}{2\pi}\left(\ln\frac{D_{cp}}{r} + \frac{\mu_r}{4}\right) \quad ,H / km \qquad (3)$$

μ_r- relative permeability of the conductor;

$D_{cp} = \sqrt[3]{D_{AB}.D_{BC}.D_{AC}}$,m –geometric average distan- ce between two line conductors.

4. Calculation of zero sequence inductance L_0

$$L_0 = \frac{\mu_0}{2\pi}\left(3\ln\frac{D_3}{\sqrt[3]{r\ .Dcp^{\ 2}}} + \frac{\mu_r}{4}\right) \quad , \ H\ /\ km \qquad (4)$$

$$D_3 = \frac{640}{\sqrt{f.\gamma_3}} \quad ,m$$

γ_3 - specific conductivity of the soil, $1/\Omega.m$.

5.Calculation of positive sequence capacitance C_1

$$C_1 \approx \frac{0,241.10^{-6}}{\lg\frac{D_{CP}}{r}} \quad , \quad F / km \qquad (5)$$

6.Calculation of zero sequence capacitance C_0

$$C_0 \approx \frac{0,803\ .10^{-8}}{\lg\frac{S_{CP}}{\sqrt[3]{r.D^2{}_{CP}}}} \quad , \quad F\ /\ km \qquad (6)$$

$S_{cp}=2.h_{cp}$;

$$h_{CP} = \sqrt[3]{h_A.h_B.h_C}\ ;$$

m - average height of the conductors.

Zero sequence inductance and positive and zero sequence resistance depend of the frequency.

III. Lightning current\`s parameters

High frequency process appears under the lightning influence on the air power line. The frequency depends of the shape and the duration of lightning current. Table 1 shows distribution of the peak value of the lightning current [4].

Table 1
Distribution of the peak value of the lightning current

P_I, %	99	90	75	50	25	10	1
$I_м$, kA_{max}	3	12	20	30	50	80	130

The lightning current has an aperiodical shape. The front duration is about a few microseconds and the impulse duration is hundreds of microseconds.

The different possibilities for current front duration determine processes with different frequency in air power lines and different parameters for R_1, R_0 and L_0.

The aim of this paper is estimation of line parameters in case of direct lightning stroke over the conductor of air power line.

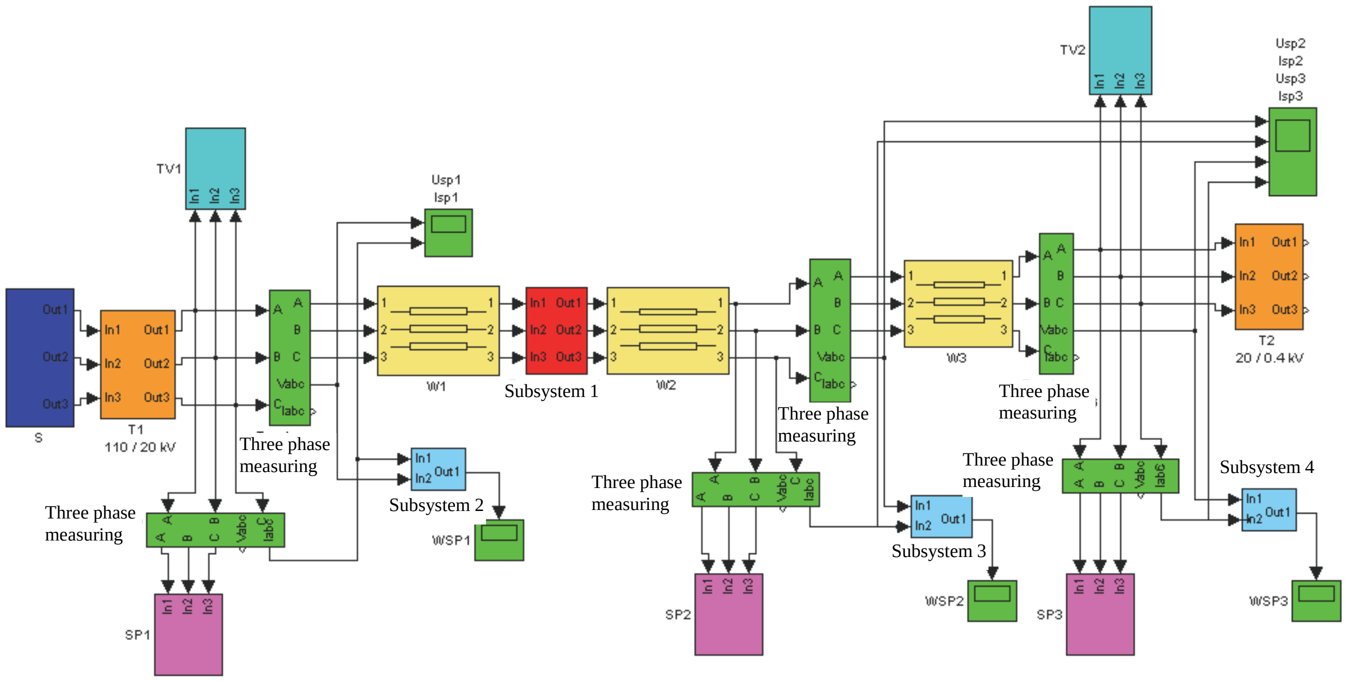

Fig.1 The model of power network 20 kV

The model of power network 20 kV is composed for identification of air power line parameters. Figure 1 shows the model. It unifies description of the following elements: power system (S); power transformer 110-20 kV (T_1); air power line (W_1,W_2) and cable power line (W_3); power transformer 20-0,4 kV (T_2); surge protective devices (SP) – metal oxide surge arresters; voltage measurement transformers (TV).

Standard blocks from Matlab Simulink library [5] are used for modeling of power line, power transformers and surge arresters.

Lightning current parameters are: amplitude 80 kA and shape 1/10 µs.

The processes in line are described whit a partial differential equations (PDE) system (7).

$$\left| \begin{aligned} -\frac{\partial U(x,t)}{\partial x} &= R.I(x,t) + L.\frac{\partial I(x,t)}{\partial t} \\ -\frac{\partial I(x,t)}{\partial x} &= C.\frac{\partial U(x,t)}{\partial t} \end{aligned} \right. \qquad (7)$$

The research is in progress whit using of solve method ode23t [5]. This method is an implementation of the trapezoidal rule using a "free" interpolant.

Current and voltage that are needed for identification of air power line parameters are measured in ten points. These points are uniformly distributed through the length of air power line.

IV. Parameter Identification

The orthogonal set of Haar functions is a group of square waves with magnitude of $\pm 2^{m/2}$ in some intervals and zeros elsewhere [1]. Since the interval on which Haar functions are defined is not suitable for solving parameter identification problems, suitable transformation is required.

The shifted Haar wavelets are defined [6] as

$$H_m^*(t) = H_1^*(t).(2^j.t - \frac{k}{2^j}), \qquad (8)$$

where: $j \geq 0$; $m = 2^j + k$; $0 < k \leq 2^j$;

$H_1^*(t)$ -scaling function, pleased during the whole observed interval [0, T].

A function $f(x,t)$ that is square integrable in the regions $t \in [0,T]$, $x \in [0,X]$, can be approximately expanded in a series of two-dimensional shifted Haar wavelets [1, 6].

Table 2
Model parameters, obtained parameters values and relative parameter errors

j	$R_0 = 3568$ $\hat{R}_0$	$L_0 = 0.0027$ $\hat{L}_0.10^{-3}$	$C_0 = 0.45.10^{-8}$ $\hat{C}_0.10^{-8}$	$R_1 = 15.2$ $\hat{R}_1$	$L_1 = 0.0012$ $\hat{L}_1.10^{-3}$	$C_1 = 0.962.10^{-8}$ $\hat{C}_1.10^{-8}$	E %
3	3872.0	2.3000	0.4294	13.9770	0.66527	1.0327	8.52
4	3728.1	0.0307	0.4174	20.5979	0.8851	0.7463	4.49
5	3672.4	0.5579	0.3009	18.3197	0.7634	0.5729	2.93
6	3638.8	0.5607	0.2701	22.0923	0.5880	0.4372	1.99
7	3618.7	0.1997	0.1343	23.3584	0.4657	0.3786	1.43
8	3594.8	0.1803	0.1268	25.7336	0.2942	0.2637	0.80
9	3581.6	0.1898	0.1023	26.6987	0.1844	0.1659	0.50

The Haar wavelets implementation reduces the problem of parameter identification to a computationally convenient form. The PDE of system (Eqs.(7)) are transformed into set of algebraic equations, and the algorithm for estimating of the parameters can be derived in a discrete form.

The identification process includes the following fundamental steps: (i) expansion of the functions of PDE into shifted two-dimensional Haar wavelets; (ii) rewriting of the PDE in the matrix form using the Haar wavelets properties and after some well known manipulations [1]; (iii) solving of the obtained matrix equation for the vector of unknown parameters using least – squares technique.

In this section *m* – file is created in Matlab based on proposed algorithm. The estimation values of the parameters for different number *m* of shifted two-dimensional Haar wavelets are calculated. The model parameters $R_0, L_0, C_0, R_1, L_1, C_1$, the obtained parameters values $\hat{R}_0, \hat{L}_0, \hat{C}_0, \hat{R}_1, \hat{L}_1, \hat{C}_1$ and the relative parameter errors E are given in Table 2.

V. Conclusion

Estimation of the air power line parameters gives a possibility for more precise modeling of processes in power line.

The line parameters in case of direct lightning stroke over the conductor of air power line by using different number of shifted two-dimensional Haar wavelets are estimated. Suitable m – file based on the proposed algorithm for parameter identification is created in Matlab and numerical results are given. The parameters estimations are obtained very accurately when bigger number of Haar wavelets is applied. Compared with the classical methods, the Haar wavelets method is computationally simplest, faster and has low computer memory requirement.

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