Investigation of the Noise Influence over Algorithms for Identification of the Air Power Line Parameters

Mariana G. Todorova[1]

Abstract – **Algorithms via two-dimensional orthogonal shifted functions for identification of the air power line parameters are considered in the paper. The noise influence over the algorithms is investigated and obtained results are analyzed.**

Keywords – **air power line, identification, noise influence.**

I. INTRODUCTION

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. 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.

A model of power network 20 kV is composed [5] for identification of air power line parameters. Standard blocks from Matlab Simulink library are used for modeling of power line. Lightning current parameters are: amplitude 80 kA and shape 1/10 μs.

The processes in the line are described whit a partial differential equations (PDE) system (1).

$$\left| \begin{array}{l} -\dfrac{\partial U(x,t)}{\partial x} = R.I(x,t) + L.\dfrac{\partial I(x,t)}{\partial t} \\ -\dfrac{\partial I(x,t)}{\partial x} = C.\dfrac{\partial U(x,t)}{\partial t} \end{array} \right. \qquad (1)$$

where:
R-resistance, Ω/km; *L*-inductance, H/km;
C- capacitance, F/km of power line;
U- phase voltages, V; *I* – phase currents, A.

If the system is transformed in symmetric co-ordinates three sequence components are used: $R_0, L_0, C_0, R_1, L_1, C_1$.

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.

[1]Mariana G. Todorova is with the Faculty of Computing and Automation, Technical University, "Studentska" str. № 1, 9010 Varna, Bulgaria, E-mail: mgtodorova@yahoo.com

The problem solved in [4, 5] is the application of two-dimensional orthogonal Haar and block – pulse functions for identification of the air power line parameters under the influence of lightning overvoltages. M – files are created in Matlab.

The aim of this paper is investigation of the noise influence over algorithms for identification of line parameters in case of direct lightning stroke over the conductor of air power line. The efficiency of the identification algorithms in case of robust measurement errors is examined too.

II. ORTHOGONAL FUNCTIONS APPLICATION FOR IDENTIFICATION OF THE AIR POWER LINE PARAMETERS

In the recent years, a spurt of activities has been witnessed on the identification of dynamic systems using orthogonal functions. Two-dimensional orthogonal functions implementation reduces the problem of parameter identification to a computationally convenient form. The partial differential equations (1), expressing the processes in the air power line, are transformed into set of algebraic equations. The algorithms are comparatively simple in form and high in numerical accuracy.

A block – pulse function (see Fig.1) is defined [3] over a time interval $t \in [0,T]$ as

$$\{B_i(t)\}, \quad i = 1, 2, ..., m, \qquad (2)$$

where:

$$\left. \begin{array}{l} B_i(t) = 1, \qquad for\ t \in [0; T/m] \\ B_i(t) = \begin{cases} 1, & for\ t \in [(i-1)T/m; iT/m] \\ 0, & elsewhere \end{cases} \\ \qquad\qquad for\ i = 2, 3, ..., m \end{array} \right\}$$

The orthogonal set of Haar functions (see Fig.2) is a group of square waves with magnitude of $\pm 2^{m/2}$ in some intervals and zeros elsewhere [1]. The Haar functions are defined as

$$H_m(t) = H_1(t).(2^j.t - \frac{k}{2^j}), \qquad (3)$$

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

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

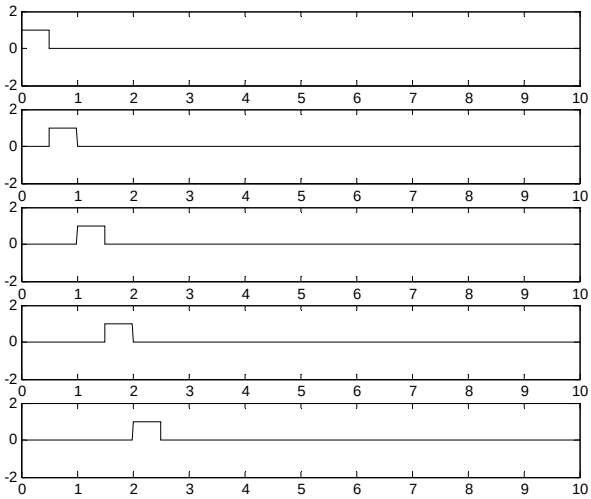

Fig. 1. Block – pulse functions (BPF)

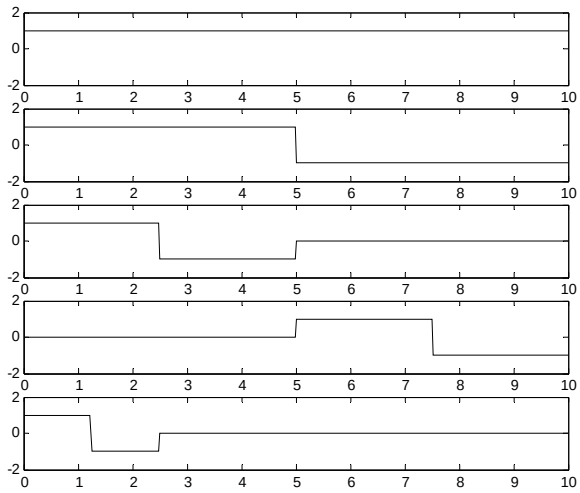

Fig. 2. Haar functions

The two-dimensional orthogonal functions $F_{ij}(x,t)$ are defined as the set of orthogonal functions over the intervals $t \in [0,T],\ x \in [0,X]$ as

$$\{F_{ij}(x,t)\} = F_i(t).F_j(x) \tag{4}$$

A function y(x,t), absolutely integrable in the region $\mathrm{t} \in [0,\mathrm{T}],\ \mathrm{x} \in [0,\mathrm{X}]$, may be approximated to

$$y(x,t) \cong \sum_{i=1}^{m}\sum_{j=1}^{n} y_{ij}F_{ij}(x,t) = F_M^T(t).Y.F_N(x) \tag{5}$$

where:

Y - two-dimensional orthogonal function coefficient matrix of the function $\mathrm{y(x,t)}$ $Y = [y_{ij}]_{m\times n}$;

$$y_{ij} = \frac{T.X}{m.n}\int_{(j-1)X/n}^{j.X/n}\int_{(i-1).T/m}^{i.T/m} y(x,t).\,dt.dx;$$

$$F_M(t) = [F_1(t)\ \ F_2(t)\ \ \dots\ \ F_m(t)]^T;$$

$$F_N(x) = [F_1(x)\ \ F_2(x)\ \ \dots\ \ F_n(x)]^T$$

The orthogonal function $F(t)$ has the property

$$\underbrace{\int_0^t \dots \int_0^t}_{r-times} F(t).dt^r = P_M^r.F(t) \tag{6}$$

If $y(x,t) \cong F_M^T(t).Y.F_N(x)$, applying the property (6) to $\mathrm{y(x,t)}$ yields

$$\underbrace{\int_0^x \dots \int_0^x}_{b-times}\underbrace{\int_0^t \dots \int_0^t}_{a-times} y(x,t).dt^a.dx^b \cong$$
$$\cong F_M^T(t).(P_M^T)^a.Y.P_N^b.F_N(x) \tag{7}$$

where P_M and P_N are correspondingly $(m\times m)$ and $(n\times n)$ integral operational matrices.

The identification process by orthogonal functions includes the following fundamental steps:

(i) expansion of the functions of PDEs into shifted two-dimensional orthogonal functions;

(ii) rewriting of the PDEs in the matrix form using the orthogonal functions properties and after some well known manipulations, i.e.

A.Q = H, (8)

where Q – vector of the unknown parameters.

(iii) solving of the obtained matrix equation for the vector of unknown parameters using least – squares technique

$$\hat{Q} = (A^T.A)^{-1}.A^T.H \tag{9}$$

III. Investigation of the noise influence over the identification algorithms

In this section two-dimensional orthogonal shifted Haar and block – pulse functions are used for identification of the air power line parameters under the influence of lightning overvoltages. The signals of the current and voltage are simulated and independent zero – mean white Gaussian noise is applied. The obtained parameter values $\hat{R}_0, \hat{L}_0, \hat{C}_0, \hat{R}_1, \hat{L}_1, \hat{C}_1$ (in the case when the ratio nose-

to-signal is q = 20%) for different numbers *m* of the orthogonal functions are given in Table 1. The relative parameter errors E are shown in Fig.3.

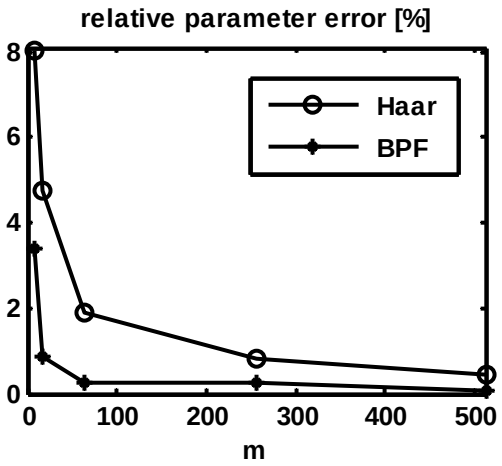

Fig.3. Relative parameter errors E

Then the efficiency of the identification algorithms in case of robust measurement errors is examined. Therefore 10% "outliers" are simulated, and their values are up to 70% wrong.

Three cases are considered: 1) the signals of the current and voltage are corrupted with a independent zero – mean white Gaussian noise with q = 20%; 2) the signals of the current and voltage are simulated and 10% "outliers" are applied; 3) the signals of the current and voltage are simulated and independent zero – mean white Gaussian noise with q = 20% and 10% "outliers" are applied. The obtained relative parameter errors E are given in Table 2.

TABLE II
OBTAINED RELATIVE PARAMETER ERRORS E

m	orthogo-nal function	E [%] case (1)	E [%] case (2)	E [%] case (3)
64	BPF Haar	0.28 1.90	0.59 1.94	0.65 2.10
512	BPF Haar	0.08 0.46	0.16 0.49	0.25 0.50

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TABLE I.
OBTAINED PARAMETERS VALUES

m	orthogonal functions	$\hat{R}_1$ Ω/km	$\hat{L}_1.10^{-3}$ H/km	$\hat{C}_1.10^{-8}$ F/km	$\hat{R}_0$ Ω/km	$\hat{L}_0.10^{-3}$ H/km	$\hat{C}_0.10^{-8}$ F/km
8	BPF Haar	21.0285 24.917	1.30 0.69	0.3371 0.9730	3693.7 3878.6	-0.49 -0.0022	0.2560 0.4306
16	BPF Haar	15.6154 23.8591	1.00 0.93	0.3293 0.7259	3598.4 3746.0	-0.45 0.146	0.2788 0.4141
64	BPF Haar	15.2390 21.3432	1.20 0.58	0.6130 0.4469	3558.1 3637.0	2.00 0.55	0.3394 0.2703
256	BPF Haar	14.6543 24.7936	1.10 0.30	0.7027 0.2631	3577.4 3596.5	2.80 0.18	0.3903 0.1268
512	BPF Haar	15.5943 26.1910	1.10 0.18	0.7055 0.1649	3565.2 3580.6	2.70 0.19	0.3672 0.1022

The accurate parameter values are: $R_1 = 15.2\,\Omega$/km, $L_1 = 0.0012$ H/km, $C_1 = 0.962.10^{-8}$ F/km, $R_0 = 3568\,\Omega$/km, $L_0 = 0.0027$ H/km, $C_0 = 0.45.10^{-8}$ F/km.

IV. CONCLUSION

The line parameters in case of direct lightning stroke over the conductor of air power line by using two-dimensional orthogonal Haar and block-pulse functions are estimated. Both the effects of the robust measurement errors and level of a measurement error are examined. Numerical results are given and the following conclusions are made.

- Considered two-dimensional orthogonal functions have interesting features - computational attraction and low computer memory requirement.
- When the system is corrupted with a noise, the algorithms give satisfactory results. As shown in Fig.3 the estimates of the line parameters via BPF-

approach are very accurate. The parameter estimations can be obtained comparatively accurate when bigger number of Haar orthogonal functions is applied.

- In case of robust measurement errors, the identification via BPF is more accurate. As shown in Table 2, the obtained via BPF relative parameter errors are approximately three-times less then the errors obtained via Haar functions.
- When the signals of the current and voltage are corrupted with a noise and "outliers" the relative parameter errors are the biggest. Using of BPF-approach is recommended.

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