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EDUCATIONAL MS EXCEL APPLICATION FOR PROCESSING DATABASE OF MEASURED NONSINUSOIDAL WAVEFORMS OF ELECTRICAL QUANTITIES

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Abstract: This contribution describes MS Excel program application for parameters determination of an electric circuit in the nonsinusoidal steady state. The parameters of the series or parallel circuit model are calculated over a time period T of measured voltage and current waveforms by means of a new method. The calculated parameters are constant coefficients of an integro-differential equation of the model circuit. The measured voltage and current are acquired by means of the digitizing oscilloscope TDS 420 from Tektronix. Widespread MS Excel environment is utilized for processing and visualization of time waveforms and results.

Keywords: MS Excel, circuit parameter, circuit model, nonsinusoidal, voltage, current

1 Introduction

Within supported thinking of students has developed an educational application in MS Excel for processing nonsinusoidal waveforms of measured voltage and current on the base of the new method created at the Department of Theoretical Electrotechnics of the Faculty of Electrical Engineering and

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Computer Science of the VSB-TU Ostrava [1]. The method, contrary to the standard method (Fourier series), evaluates all three circuit parameters and gives correct values of the powers (apparent, active, reactive) under nonsinusoidal, periodical conditions. Moreover, the one is suitable for study of the electromagnetic phenomena of a measured circuit [2].

2 Characteristic of the application

The MS Excel application with the name *ObvParEn.xls* is intended for students of theoretical electrotechnics. The one calculates circuit parameters, immittance, RMS values and power of the measured circuit including its components, THD values and it provides verification of the circuit model. Further, it allows to read acquired data from the digitizing oscilloscope TDS 420 as well as to visualize and to study the electromagnetic phenomena of the circuit characterized by the measured voltage u and the measured current i.

The application is assembled from the *Data* and *Calculates* sheets, the *Settings* and *TDS420* forms and from the *Test of Linearity*, the *Components of u/i* and from the *Components of p* graphs. Processing the digitized voltage and current waveforms, settings the visualized values or units is performed by subroutines written in VBA. Algorithms of numerical mathematics, used for calculation of the values, utilize the duality principle (in text it is differed with symbol /) of the electrical circuits shown in fig. 1.

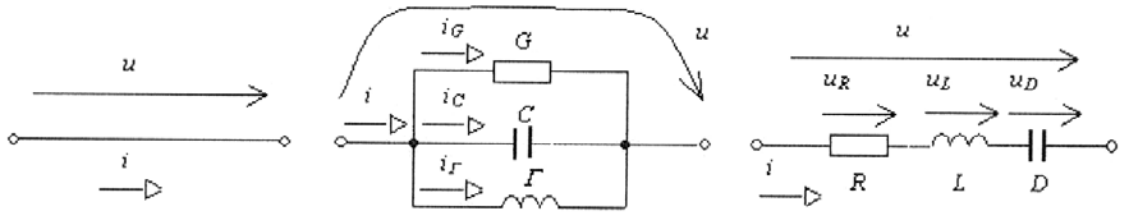

Fig. 1 Series and parallel connection of circuit model

2.1 Sheets of the application

View of the *Data* sheet is shown in Fig. 2. In this main sheet, after voltage and current file loading *(click* Read files... *command button)*: in column A the numbers of samples n_i, in column B the time instants of sampling t_i, in column C the instant values of samples u_i/ i_i and the graph with waveforms of the loaded electrical quantities are displayed. The period T of quantities is defined by the time interval (t_a, t_b) or by the samples (n_a, n_b) *(click* n_a/ t_a and n_b/ t_b *text box with list box)*,

$$T = t_b - t_a = \frac{n_b - n_a}{f_{vz}},$$

where f_{vz} is the sampling frequency.

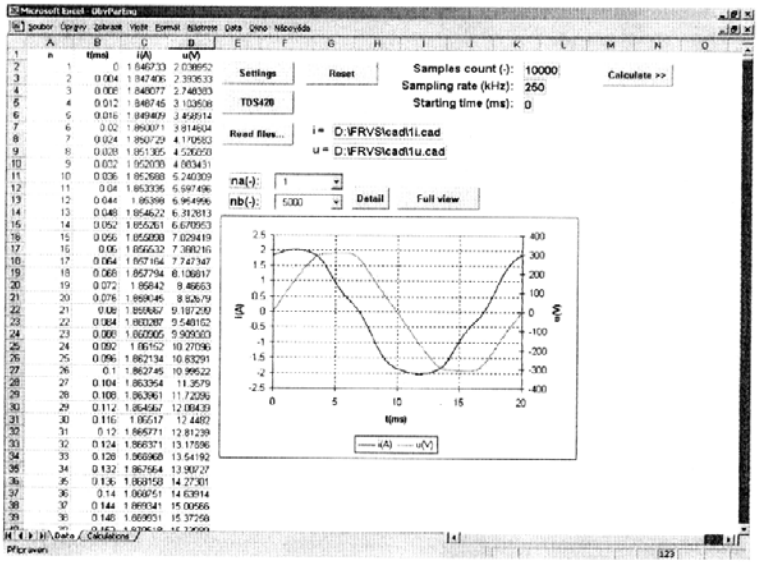

Fig 2 Sheet *Data*

The *Calculations* sheet displays symbols *(click* Calculate *command button in the Data sheet)*, units and values calculated by the following formulae over the period T:

the parameters

$$R = \frac{(u,i)}{\|i\|^2} \,/\, G = \frac{(i,u)}{\|u\|^2},$$

$$L = \frac{(u,i')\cdot\|i^x\|^2 + (u,i^x)\cdot\|i\|^2}{\|i'\|^2\cdot\|i^x\|^2 - \|i\|^4} \,/\, C = \frac{(i,u')\cdot\|u^x\|^2 + (i,u^x)\cdot\|u\|^2}{\|u'\|^2\cdot\|u^x\|^2 - \|u\|^4},$$

$$D = \frac{(u,i')\cdot\|i\|^2 + (u,i^x)\cdot\|i'\|^2}{\|i'\|^2\cdot\|i^x\|^2 - \|i\|^4} \,/\, \Gamma = \frac{(i,u')\cdot\|u\|^2 + (i,u^x)\cdot\|u'\|^2}{\|u'\|^2\cdot\|u^x\|^2 - \|u\|^4},$$

where the function (,) indicates the inner product of two functions and the function $\|\ \|$ indicates the norm of the function, the symbol ' denotes the time derivative of the function and the symbol ^{x} denotes the integral of the function with zero the mean value,

the immittances

$$Z = \frac{U}{I} \,/\, Y = \frac{I}{U}, \qquad Z_{as} = \sqrt{Z_P^2 + Z_Q^2} \;/\; Y_{as} = \sqrt{Y_P^2 + Y_Q^2},$$

$$Z_P^2 = R^2 \;/\; Y_P^2 = G^2,$$

$$Z_Q^2 = Z_C^2 + Z_\Gamma^2 - 2Z_V^2 = \left(L\frac{\|i'\|}{\|i\|}\right)^2 + \left(D\frac{\|u^x\|}{\|i\|}\right)^2 - 2LD \,/$$

$$Y_Q^2 = Y_C^2 + Y_\Gamma^2 - 2Y_V^2 = \left(C\frac{\|u'\|}{\|u\|}\right)^2 + \left(\Gamma\frac{\|u^x\|}{\|u\|}\right)^2 - 2C\Gamma$$

the RMS values

$$U = \frac{\|u\|}{\sqrt{T}} / I = \frac{\|i\|}{\sqrt{T}},$$

$$U_{as}^2 = (RI)^2 + (LI')^2 + (DI^x)^2 - 2LD\,I^2 = U_R^2 + U_L^2 + U_D^2 - 2LD\,I^2 =$$

$$= U_R^2 + U_L^2 + U_D^2 - 2U_V^2 /$$

$$I_{as}^2 = (GU)^2 + (CU')^2 + (\Gamma U^x)^2 - 2C\Gamma\,U^2 = I_G^2 + I_C^2 + I_\Gamma^2 - 2C\Gamma\,U^2 =$$

$$= I_G^2 + I_C^2 + I_\Gamma^2 - 2I_V^2 ,$$

$$U_Q^2 = U_L^2 + U_D^2 - 2U_V^2 / I_Q^2 = I_C^2 + I_\Gamma^2 - 2I_V^2 .$$

Verification of the calculated (linearized) values of the circuit parameters is carried out by comparing of the calculated values *Uas*/ I_{as} with the measured values *U*/ *I*.

the powers

$$P = UI, \qquad P_{as}^2 = P_P^2 + P_Q^2 = (I_P^2 + I_Q^2)U^2 = (U_P^2 + U_Q^2)I^2 ,$$

$$P_R = U_R I / P_G = I_G U , \quad P_L = U_L I / P_C = I_C U , \quad P_D = U_D I / P_\Gamma = I_\Gamma U ,$$

$$P_V = U_V I = I_V U , \quad P_P = P_R = P_G , \quad P_Q = U_Q I = I_Q U$$

the fundamental harmonic RMS values

$$I_{(1)} = \frac{\|i_{(1)}\|}{\sqrt{T}} / U_{(1)} = \frac{\|u_{(1)}\|}{\sqrt{T}},$$

where index $_{(1)}$ denotes the fundamental harmonic components of the electrical quantities with the mutual phased drift $\varphi_{(1)}$

the fundamental harmonic immittance, reactance or susceptance

$$Z_{(1)} = \frac{U_{(1)}}{I_{(1)}} / Y_{(1)} = \frac{I_{(1)}}{U_{(1)}}, \quad X_{(1)} = Z_{(1)} \sin\varphi_{(1)} / B_{(1)} = Y_{(1)} \sin\varphi_{(1)}$$

the fundamental harmonic parameter

$$R_{(1)} = Z_{(1)} \cos\varphi_{(1)} / G_{(1)} = Y_{(1)} \cos\varphi_{(1)}$$

the fundamental harmonic powers (apparent, active and reactive)

$$S_{(1)} = U_{(1)} I_{(1)}, \qquad P_{(1)} = S_{(1)} \cos\varphi_{(1)}, \qquad Q_{(1)} = S_{(1)} \sin\varphi_{(1)}$$

the voltage and current THD

$$\text{THD U} = 100 \sqrt{\frac{U^2}{U_{(1)}^2} - 1}, \qquad \text{THD I} = 100 \sqrt{\frac{I^2}{I_{(1)}^2} - 1} \ (\%).$$

2.2 Forms of the application

The *Settings* and *TDS420* forms are activated by click on the command buttons (caption *Settings* and *TDS420*) in the *Data* sheet. The *Settings* form allows to set up the kind of the circuit model (series or parallel) and parameters

of files (extension, data selection). Further, it allows to set up the prefix of the units of the shown quantities and circuit parameters as well as the FIR filter parameters (order, normalized Nyquist frequency) and the order of the fundamental harmonic. Filtrering of the electrical quantities is realized by the low-pass FIR filter with the Hamming window.

The *TDS420* form makes it possible to read acquired data from the digitizing oscilloscope TDS 420 and transfered from it to PC via GPIB interface.

2.3 Graphs of the application

In the *Test of linearity* graph are compared the calculated time waveforms of the electrical quantities u_{as}/ i_{as} with the measured time waveforms u/ i according to the following integro-differential equations

$$u_{as} = u_R + u_L + u_D = Ri + Li' + Di^x /$$

$$i_{as} = i_G + i_C + i_\Gamma = Gu + Cu' + \Gamma u^x .$$

The time waveform of the difference u - u_{as}/ $i - i_{as}$ gives information about the test result of circuit linearity ($u = u_{as}$/ $i = i_{as}$ linear circuit, $u \neq u_{as}$/ $i \neq i_{as}$ non-linear circuit).

In the *Components of u/ Components of i* and the *Components of p* graphs are vizualized the calculated time waveforms of the components electrical quantities u_R/ i_G, u_L/ i_C, u_D/ i_Γ, u_Q/ i_Q, u_{as}/ i_{as} and the ones of the instantaneous powers p_{as}, p_R/ p_G, p_L/ p_C, p_D/ p_Γ, p_P, p_Q.

3 Conclusion

The application ObvParEng.xls is suitable not only for the education but also for evaluation of influence the distorted voltage and current waveforms on an electrical equipment in the practice. The applied method allows to determine all three parameters of the series or parallel circuit model and, in compliance with basic physical principles, to correctly determine powers of the measured circuit under nonsinusoidal, periodical conditions. The method makes it possible to study the electromagnetic phenomena of the measured circuit on the base of the calculated values of the circuit parameters.

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