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Transient analysis module from an object oriented electrical circuit designer application

***Abstract**. The paper deals with a software module, developed by the first Author, from a complex electrical circuit designer application. This analysis module presents the transient response of the designed network to the excitation applied to it. The results can be calculated by some different type ordinary differential equation solvers. The most important aim of this part of the research is creating a new algorithm, which the all different type ordinary differential equation solvers can be used with one algorithm.*

Streszczenie.** Artykuł dotyczy modułu oprogramowania umieszczonego w kompleksowym systemie projektującym obwody elektryczne. Analiza modulu przedstawia odpowiedz stanu przejściowego (transient) zaprojektowanego pbwodu na zaplikowane wzbudzenia. Wyniki mogą być uzyskiwane przez solvery różnego rodzaju równań różniczkowych. Najważniejszym celem tej części badań jest stworzenie nowego algorytmu, łączącego różnego rodzaju solvery w jeden algorytm. **(Moduł do analizy stanu przejściowego umieszczony w systemie projektującym obwody elektryczne)

Keywords: , circuit analyzer, transient analysis, differential equation solver.
Słowa kluczowe: analizator obwodów, analiza stanu przejściowego, solver równań różniczkowych.

Introduction

This paper deals with a new software module from a complex electrical circuit designer application [1,2] (Fig. 1), developed by the first Author, what have been improved for two and a half years.

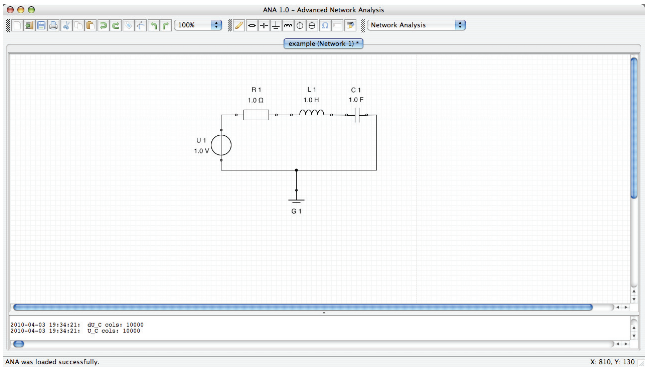

Fig. 1. The graphical interface of the software, developed by the first Author

This analysis module presents the transient response of the designed network to the excitation applied to it. The result can be voltage, current or power function of the time [3]. The excitations can be different type of time functions, due to all, unit step, Dirac impulse, square, triangle, sine and cosine wave functions.

The results can be calculated by some different type ordinary differential equation solvers, due to all by the Euler algorithms, by the Galerkin algorithm [4], by the Cranck-Nicholson algorithm and by the Predict-Correct scheme [5].

The most important aim of this part of the research is creating a new algorithm, which the all different type ordinary differential equation solvers can be used with one algorithm.

About the analysis, resulting the time function

The transient analysis is based on the matrix equation [7]:

$$(1)\quad \begin{bmatrix} \underline{\underline{0}} & \underline{\underline{A}}_U^T & \underline{\underline{0}} & \underline{\underline{0}} \\ \underline{\underline{A}}_U & \underline{\underline{A}}_R \underline{\underline{G}} \underline{\underline{A}}_R^T & \underline{\underline{A}}_C \underline{\underline{C}} & \underline{\underline{0}} \\ \underline{\underline{0}} & \underline{\underline{A}}_C^T & \underline{\underline{0}} & \underline{\underline{0}} \\ \underline{\underline{0}} & \underline{\underline{A}}_L^T & \underline{\underline{0}} & -\underline{\underline{L}} \end{bmatrix} \begin{bmatrix} \underline{i}_U \\ \underline{\varphi}_1 \\ \frac{d\underline{u}_C}{dt} \\ \frac{d\underline{i}_L}{dt} \end{bmatrix} = \begin{bmatrix} \underline{\underline{0}} & \underline{\underline{0}} \\ \underline{\underline{0}} & -\underline{\underline{A}}_L \\ \underline{\underline{1}}_C & \underline{\underline{0}} \\ \underline{\underline{0}} & \underline{\underline{0}} \end{bmatrix} \begin{bmatrix} \underline{u}_c \\ \underline{i}_L \end{bmatrix} + \begin{bmatrix} \underline{\underline{1}}_U & \underline{\underline{0}} \\ \underline{\underline{0}} & -\underline{\underline{A}}_I \\ \underline{\underline{0}} & \underline{\underline{0}} \\ \underline{\underline{0}} & \underline{\underline{0}} \end{bmatrix} \begin{bmatrix} \underline{u}_s \\ \underline{i}_s \end{bmatrix}$$

The solution of the matrix equation system gives the vectors of voltages $\underline{u}_C$ and $\underline{u}_s$ currents $\underline{i}_L$ and $\underline{i}_s$ and the vectors of $\frac{d\underline{u}_C}{dt}$ and $\frac{d\underline{i}_L}{dt}$, from which the normal form of the state equation can be obtained [5,6].

The results can be calculated by some different type of ordinary differential equation solvers, which can be chosen in a dialog box (Fig. 2), after starting the analysis.

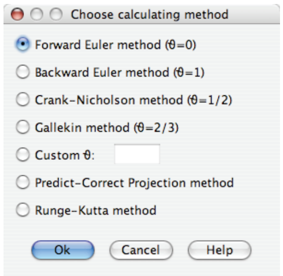

Fig. 2. Changing attributes of sine wave

Ordered and simplified the equation by using $\dot{x} = \frac{x_{n+1} - x_n}{\nabla t}$, the next results can be given:

$$(2)\quad \begin{bmatrix} \dot{\underline{u}}_c \\ \dot{\underline{i}}_L \end{bmatrix} = \left[\underline{\underline{A}}\right] \begin{bmatrix} \underline{u}_c \\ \underline{i}_L \end{bmatrix} + \left[\underline{\underline{B}}\right] \begin{bmatrix} \underline{u}_s \\ \underline{i}_s \end{bmatrix}$$

$$(3)\quad \begin{bmatrix} \frac{\underline{u}_{C,\,n+1} - \underline{u}_{C,\,n}}{\Delta t} \\ \frac{\underline{i}_{L,\,n+1} - \underline{i}_{L,\,n}}{\Delta t} \end{bmatrix} = \left[\underline{\underline{A}}\right] \begin{bmatrix} \underline{u}_{C,\,n} \\ \underline{i}_{L,\,n} \end{bmatrix} + \left[\underline{\underline{B}}\right] \begin{bmatrix} \underline{u}_{s,\,n+1} \\ \underline{i}_{s,\,n+1} \end{bmatrix}$$

From the form (3) can be seen, that it is a same equation form like

$$(4)\quad \frac{x_{n+1} - x_n}{\Delta t} \cong f(x_n, t_n).$$

(4) can be solved by using the Forward Euler method [6]:

$$(5)\quad x_{n+1} \cong x_n + \Delta t \cdot f(x_n, t_n),$$

by the Backward Euler method (solved by the Predict-Correct scheme) [6]:

(6) $$x_{n+1} \cong x_n + \Delta t \cdot f(x_{n+1}, t_{n+1})$$

(7) $$x_{n+1}^{(0)} \approx x_n + \Delta t \cdot f(x_n, t_n)$$

(8) $$x_{n+1}^{(j+1)} \approx x_n + \Delta t \cdot f(x_{n+1}^{(j)}, t_n)$$

(9) $$\left\| \frac{x_{n+1}^{(j+1)} - x_{n+1}^{(j)}}{x_{n+1}^{(j+1)}} \right\| < 10^{-8},$$

by Crank-Nicholson method [6]:

(10) $$x_{n+1} \cong x_n + \frac{1}{2}\Delta t \cdot [f(x_n, t_n) + f(x_{n+1}, t_{n+1})],$$

and by Galerkin method [4]:

(11) $$x_{n+1} \cong x_n + \frac{2}{3}\Delta t \cdot f(x_n, t_n) + \frac{1}{3}\Delta t \cdot f(x_{n+1}, t_{n+1}).$$

The results can be compared to thanks for the different solvers. The time functions can be analyzed with a little function viewer application (Fig. 3), developed by the first Author. After clicking on the analyzable dipole of the current network, the voltage, current or the power time function of the actually component as it can be seen in the viewer.

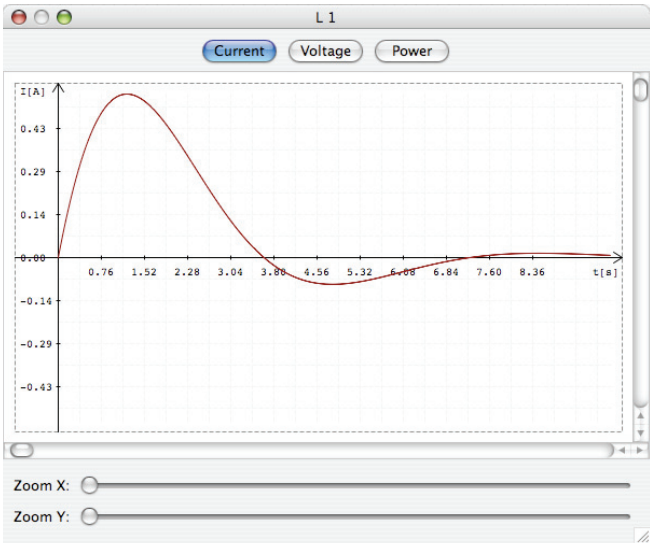

Fig. 3. Function viewer application

About the new algorithm

With a ϑ constant - what must be between 0 and 1 – and with the

(12) $$\frac{x_{n+1} - x_n}{\Delta t} = \vartheta \frac{dx_{n+1}}{dt} + (1-\vartheta)\frac{dx_n}{dt}$$

(13) $$x_{n+1} \approx x_n + (1-\vartheta)\Delta t \cdot f(x_n, t_n) + \vartheta \Delta t \cdot f(x_{n+1}, t_{n+1})$$

equations [7], using the Predict-Correct scheme, a new simplified algorithm can be given, which what, all the different type of ordinary differential equation solvers can be used with one algorithm.

The type of the solvers depended by the value of ϑ. If $\vartheta = 0$, the Backward Euler method, if $\vartheta = 1$, the Forward Euler method, if $\vartheta = 1/2$, the Crank-Nicholson method, and if the $\vartheta = 2/3$, the Galerkin method can be given. The algorithm can be seen in Fig. 4.

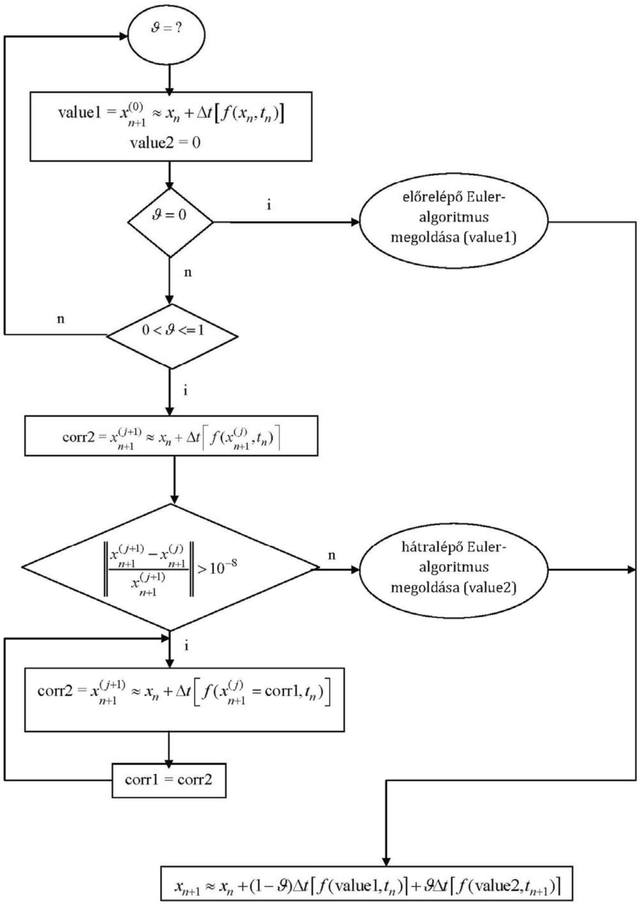

Fig. 4. The new solver algorithm

Different type of excitations

The excitations can be different type of time functions, what can be chosen - after double-clicking on the graphic of the source (Fig. 5) - in a dialog box (Fig.6).

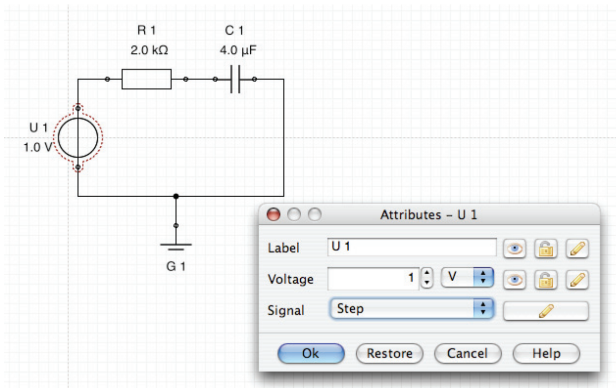

Fig. 5. The attributes dialog box of U1 voltage source

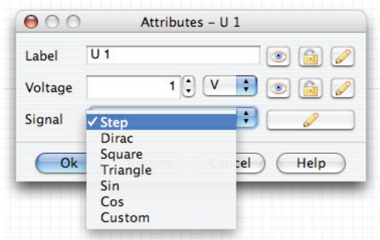

Fig. 6. Changing the types of the excitation

The time function can be unit step, Dirac impulse, square, triangle, sine and cosine wave functions. Every type of functions has a lot of attributes that can be changed by the decision of the user:

– unit step: amplitude (A), start of edge (T)
– Dirac Pulse: amplitude (A), width of pulse (T),
– square wave: amplitude (A), frequency (f), rise/fall time (τ), period (T),
– triangle wave: amplitude (A), frequency (f), period (T),
– sine wave: amplitude (A), frequency (f), phase (θ), period (T),
– cosine wave: amplitude (A), frequency (f), phase (θ), period (T).

These attributes can be chosen in a dialog box (Fig. 7).

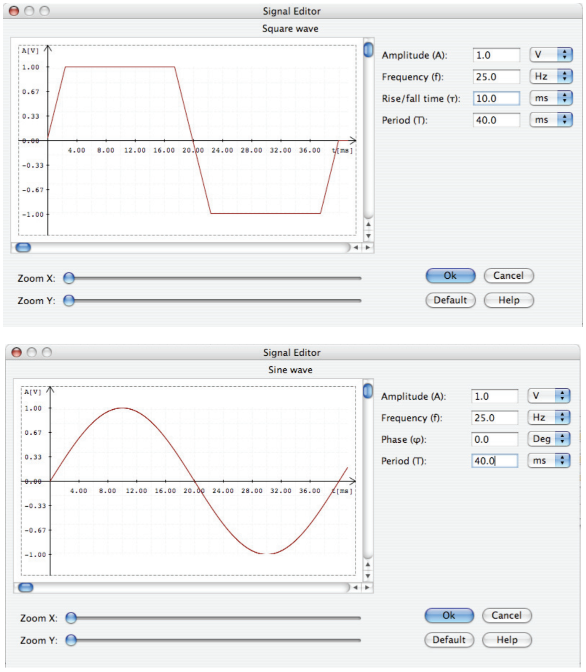

Fig. 7. Changing attributes of a triangle and a sine wave

Example 1

In small circuits, with the different type of solvers, the same results must be obtained. After testing the new algorithm, the next same results could be given to the all type of solvers.

The example circuit and the start of the analysis can be seen in Fig. 8. The RLC circuit parameters are: $U_1 = 1V$, $R_1 = 2k\Omega$, $L_1 = 4mH$ and $C_1 = 2\mu F$ [8].

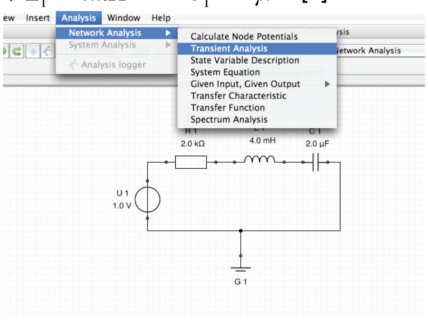

Fig. 8. Starting the analysis

The results can be seen in Fig. 9 – Fig. 20.

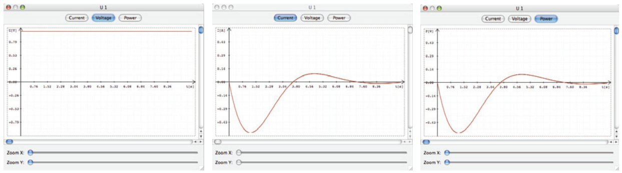

Fig. 9 - 11. Voltage, current and power of U1 voltage source

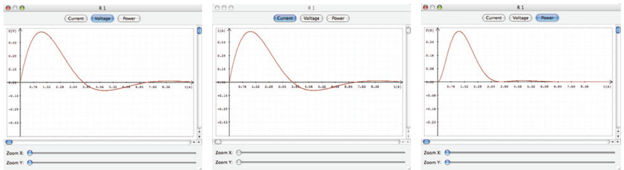

Fig. 12 - 14. Voltage, current and power of R1 resistor

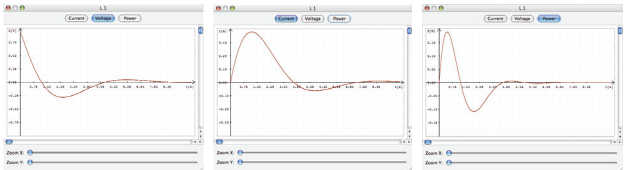

Fig. 15 - 17. Voltage, current and power of L1 coil

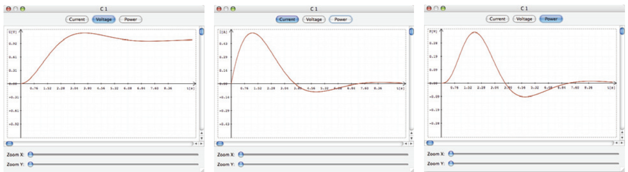

Fig. 18 - 20. Voltage, current and power of C1 capacitor

Example 2

The second example shows the results of the example RC circuit (Fig. 21.) to different type excitations [9].

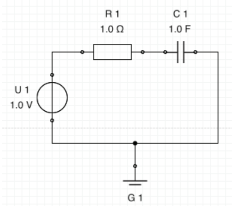

Fig. 21. The example RC circuit

In every case (Fig. 22 - 33) the first picture shows the excitations, and the second shows one result time function from a component of the current network.

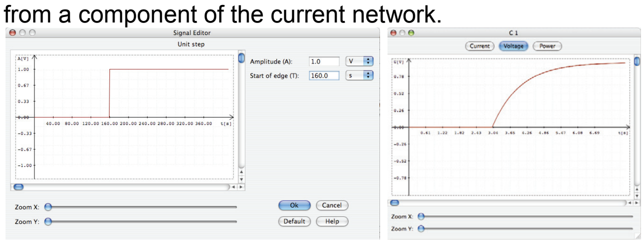

Fig. 22 - 23. Unit step excitation with the voltage result of C1 capacitor

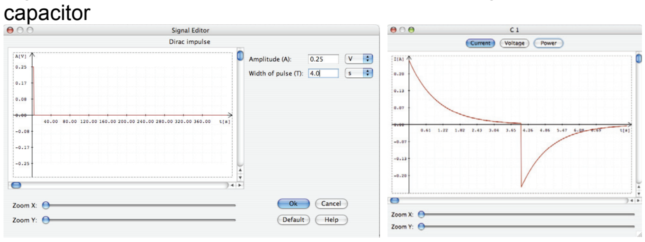

Fig. 24 - 25. T=4s with of pulse excitation with the current result of C1 capacitor

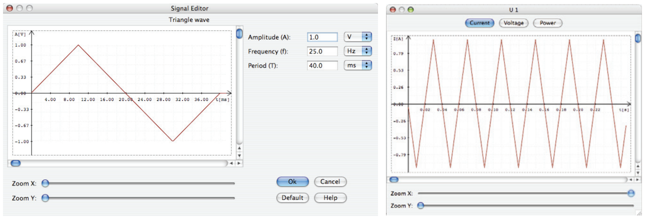

Fig. 26 - 27. T=40ms triangle wave excitation with the 100% zoomed current result of U1 voltage source

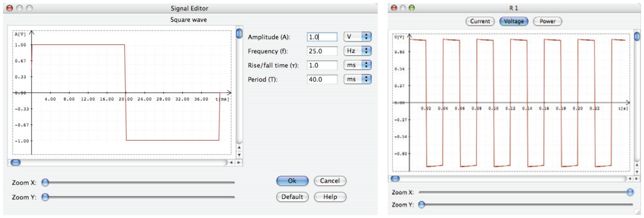

Fig. 28 - 29. T=40ms square wave excitation with the 100% zoomed voltage result of R1 resistor

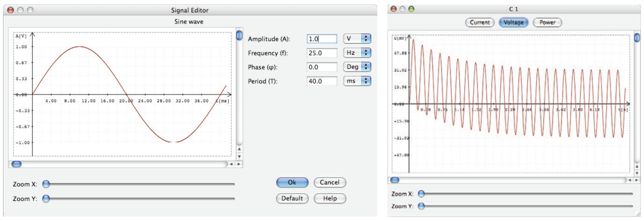

Fig. 30 - 31. T=40ms sine wave excitation with the voltage result of C1 capacitor

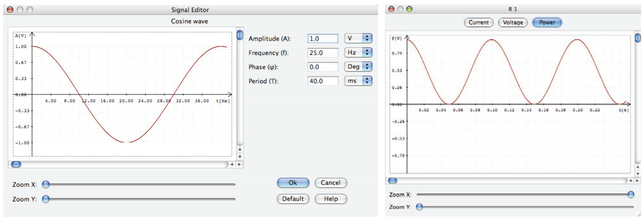

Fig. 32 - 33. T=40ms cosine wave excitation with the power result of R1 resistor

Conclusions

In conclusion, the deal of this paper is to show a little part of a huge application. The aim of this research is to implement a lot of analysis modules, like this.

The most important part of the work of last period, was creating a new algorithm, which can be solving the different type differential equation solvers with one step. The other part of the work was implementing different type excitations to the application, and testing the given time results with lot of different circuits.

Until our days, the software has three implemented and tested complex analysis module. With the application the nodal potentials, the currents, voltages, powers and the time results of dipoles, the eigenvalues, and the network equations can be calculated. Lot of type networks can be edited, analyzed, and tested and their work can be followed with some other module of the program.

The next part of the work is the Fourier-transform, and the Spectral Analysis module.

The other future plans are due to all, calculate and display transfer characteristics, transfer function, shape preserving signal transmission, Laplace-, z-transform, Bode plot, and Nyquist plot. After all, the application will be improved with many other services [8].

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