

# Analysis of the Electrical Engineering Problems Using Computer Tools

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**Abstract:** This paper shows possibilities using of computer tools in Basic Circuit Theory. There is a brief summary of the computer approach in Electrical Engineering Education in the world, which we found among books, papers, and the web presentations.

The survey of the computer exercises prepared at the Department of Circuit Theory of the Czech Technical University in Prague is introduced. The exercises cover following topics: the harmonic steady state, circuit equations, transients, and operational analysis. In periodical non-harmonic steady state analysis students are solving problems of integrating and derivating networks with different input signals. Exercise according to the frequency response has two complementary parts - laboratory and computing. This is example of appropriate supplement, where students are able to see actual and simulated circuit behavior. Generalized nodal voltage analysis method presents the next topic available for MATLAB exercise for very easy computation with matrices, their determinants and sub-determinants. Students prepare matrices of two-stage amplifier as homework. The transfer function, input and output voltages are computed during this lesson. Exercise for transmission line with distributed parameters has graphic user interface allowing to demonstrate transients on the lossless transmission line. Students are able to observe transient waves caused by the connection of the DC voltage source to the transmission line input and propagation of the short rectangular voltage impulse along the transmission line. Students can also study standing waves on the transmission line using the demo file sinusoidal steady state on a transmission line. Program environment allows change the line parameters and the load impedances at the both line ends. The last set of tasks can demonstrate the elementary methods of non-linear DC analysis, especially the problems of convergence and accuracy. Students are able to observe the iteration process step by step and to change formulae inside loop and circuit parameters by simple way.

**Keywords:** circuit theory, analysis, MATLAB

## 1. Introduction

The theory of electrical circuits represents one of most important parts of the Electrical Engineering education. The main aims of this course are to obtain the knowledge of circuit analysis and synthesis and to see the experience of actual behavior of typical circuits. This purpose needs using of powerful software mathematical tools.

The MATLAB is numeric computation software for package engineering and scientific calculations. The main reasons for wide spread using of MATLAB are following [1]: easy to learn and use; powerful, flexible and extensible; accurate, robust and fast; widely used in engineering and science; backed by a professional software company.

This paper presents an approach according to teaching of circuit analysis topics using specially designed exercises that can be done on the base of MATLAB running on personal computers.

## 2. Using of MATLAB in Electrical Engineering Education

We would like to inform in this paragraph about selected "circuit MATLAB sources" which we found among books, papers, and the web presentations.

"Classical book" for engineering problem solving in MATLAB is the book [1]. Many chapters show inspirative examples and problems for EE education. The book [2] includes disc with MATLAB Circuit Toolbox. This toolbox is focused to the problems from nodal and mesh analysis and dynamic analysis (Bode plots, natural frequencies, transient responses and residue calculation). The Circuit Theory textbook [3] is accompanied by number of

MATLAB problems and examples. The book [4] is written for first course in circuits and contains supplement: Using Computer Tools for Electric Circuits and introduces MATLAB for solving circuit problems. The book [5] is focused to the signal and systems but has many MATLAB examples integrated throughout the text available for circuit theory. Several examples are included in the book [6] that illustrate the use of MATLAB to solve problems involving electric circuits. The book [7] provides introduction to MATLAB and demonstrates the use of MATLAB for solving electronic problems. It outlines various ways MATLAB solves Circuit analysis problems, and shows the flexibility of MATLAB. Topics include plotting functions, control statements, two-port networks, Fourier analysis, diodes, semiconductor physics, operational amplifiers, and transistor circuits. The set of MATLAB M-files is available on disk bound into the book. MATLAB M-files can be found throughout the book [8]. The book focuses for practicing electronics professionals. The book [9] is written for undergraduate students taking their first course on linear electric circuits (basic circuit concepts and analysis methods, node and mesh equations, phasors, the s-domain, Fourier series, and Laplace transforms). There is an appendix on circuit analysis with MATLAB, which covers an introduction to MATLAB, resistive circuits, AC circuits, frequency response, and Laplace transform. The book [10] is written for advanced undergraduate study in circuit analysis. This book employs differential and integral calculus and transform methods with a strong applied emphasis. The last section of each chapter provides MATLAB example, illustrating some of the most useful operations that support circuit analysis.

The paper [11] describes RL and RC circuits transient analysis in detail. This paper is also appropriate for a quick introduction into MATLAB. The use of MATLAB in Laplace analysis is described in [12]. Examples for partial fraction expansion, time and frequency domain analysis could be find there.

There are some tutorials on the web of Memphis University [21]. The first tutorial deals with mathematical operations for voltages and currents in electrical circuits. The second one represents analytical study of the step response (first and second order of the electrical circuits), and the third one shows the study of frequency responses, resonance and magnetic coupling of electrical circuits. It is possible to find a few interesting papers from this area in the WWW electronic version of the ASEE/IEEE proceedings [22]. Most convenient paper "Teaching AC Circuit Analysis with MATLAB" describes MATLAB programs from three phase circuit analysis and frequency characteristics (pole - zero plots and magnitude responses). M-files collection of Laura Knauth [23] from Arizona State University contains many files for basic Electrical Engineering courses focused to the Electromagnetic Theory. Some personal homepages of Circuit Theory teachers show the MATLAB using in EE education (e.g. homepage of Dr. Whetten [24] from Embry - Riddle University).

### 3. MATLAB exercises in the Department Circuit Theory of CTU

The Circuit Theory I and II are obligatory courses for all study branches in Electrical and Information Engineering curricula.

The Basic Circuit Theory I taught during the 2<sup>nd</sup> semester of study is based on the physical approach for DC, AC and transient analysis of simple linear circuits. The Basic Circuit Theory II represents advanced study of Circuit Theory that needs computer support for solving of general problems.

A few MATLAB exercises have been prepared at the Department of Circuit Theory of the Czech Technical University during last two years.

The MATLAB exercises replaced some exercises with Turbo Tutor [13]. Because the source code for Turbo Tutor is easy to transfer in m-files, there is a good utilization of our older works.

At the beginning of Circuit Theory II students are introduced with basic works in MATLAB [14]. Demo files, help object, commands for arithmetic and basic plotting are explained in the introductory lesson. Next the matrix solution of circuit equations and examples for phasor computing with complex number are shown. During the end of this first lesson students learn to generate and to display different time waveforms. Students are able to apply knowledge gained in this lesson in the following topics from the Circuit Theory I: *Harmonic steady state* (phasors, impedances, three phase systems), *circuit equations*, and *transients*.

In periodical *non-harmonic steady state analysis* [15] students are solving problems from the textbook [19] (integrating and derivating networks with different input signals).

Exercise according to the *frequency response* [16] has two complementary parts: laboratory and computing (MATLAB). This is example of appropriate supplement, where students are able to see actual and simulated circuit behavior.

*Generalized nodal voltage analysis method* [17] presents the next topic available for MATLAB exercise for very easy computation with matrices, their determinants and sub-determinants. Students prepare matrices of two-stage amplifier as homework. The transfer function, input and output voltages are computed during this lesson [20].

Exercise for *transmission line with distributed parameters* [18] has graphic user interface allowing to demonstrate transients on the lossless transmission line. Students are able to observe transient waves caused by the connection of the DC voltage source to the transmission line input and propagation of the short rectangular voltage impulse along the transmission line. Students can study standing waves on the lossless transmission line using the demo file sinusoidal steady state on a transmission line. Program environment allows to change the line parameters and the load impedances at the both line ends.

The last set of tasks can demonstrate the elementary methods of *non-linear DC analysis*, especially the problems of convergence and accuracy.

```

% DEMONSTRATION OF PICCARD'S METHOD
% parameters for Thevenin circuit :
Ui=600; % open circuit voltage
Ri=1e5; % internal resistor
Ik=Ui/Ri; % short current
i=linspace(0,Ik,100); % currents
u=2927*i.^0.287; % VA- characteristics
plot(u,i) % plot VA char
line([Ui 0],[0 Ui/Ri]); % plot load line
hold on
k=1; % number of iteration
I(k)=Ik/2; % current start. value
error(k) = I(k);
while error(k) > 0.1*I(k)
    U(k+1)=2927*I(k).^0.287;
    %iteration formule
    I(k+1)=(Ui-U(k+1))/Ri;
    plot([U(k) U(k+1)],[I(k) I(k)],'r:');
    plot([U(k+1) U(k+1)],[I(k) I(k+1)],'r:');
    error(k+1) = abs(I(k+1)-I(k))
    k=k+1;
    pause(1)
end;
hold off
title ('Packard method')
xlabel('Voltage [Volts]')
ylabel('Current [Ampers]')
[(1:k)' U' I' error']

```

Fig. 1. Demonstration m-file for Piccard's method

The Figure 1 shows M-file for Piccard's method demonstration, the Figure 2-4 show the example of the iteration process step by step. Students may change formulæ inside loop and circuit parameters by simple way. It gives a good practice about the speed and accuracy of different method.

#### 4. Conclusions

The MATLAB environment is successfully used for 1000 students of the Czech Technical University per each term. The use of MATLAB for the mathematical portions of circuit analysis is well receiving by the students. The MATLAB provides a better understanding of Circuit Theory both in the time and frequency domains, and the complex relationships between these domains.

<b>k</b>	<b>U(k)</b>	<b>I(k)</b>	<b>error</b>
1	0	0.0030	0.0030
2	552.5308	0.0005	0.0025
3	325.5014	0.0027	0.0023
4	538.6216	0.0006	0.0021
5	350.4154	0.0025	0.0019
6	524.1121	0.0008	0.0017
7	372.4193	0.0023	0.0015
8	510.4117	0.0009	0.0014
9	390.5880	0.0021	0.0012
10	498.3680	0.0010	0.0011
11	404.9864	0.0020	0.0009
12	488.2827	0.0011	0.0008
13	416.1341	0.0018	0.0007
14	480.1032	0.0012	0.0006
15	424.6592	0.0018	0.0006
16	473.6059	0.0013	0.0005
17	431.1399	0.0017	0.0004
18	468.5144	0.0013	0.0004
19	436.0545	0.0016	0.0003
20	464.5597	0.0014	0.0003
21	439.7789	0.0016	0.0002
22	461.5059	0.0014	0.0002
23	442.6021	0.0016	0.0002
24	459.1572	0.0014	0.0002
25	444.7435	0.0016	0.0001

Fig. 2. Iteration process in MATLAB for Piccard's method

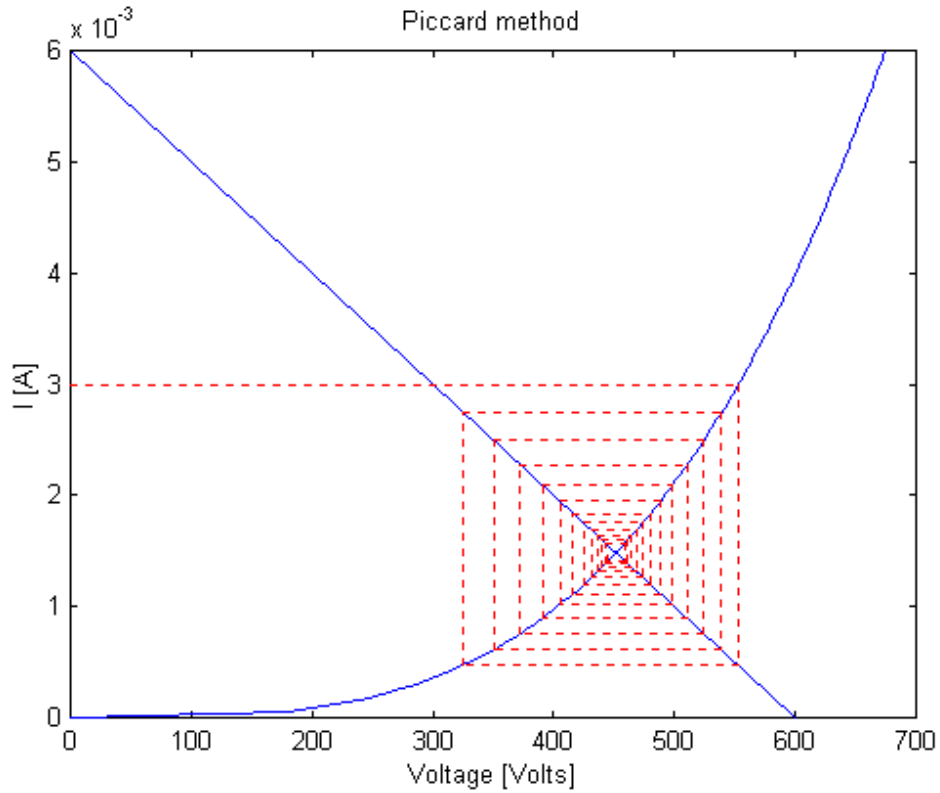


Fig. 3. Iteration process in MATLAB

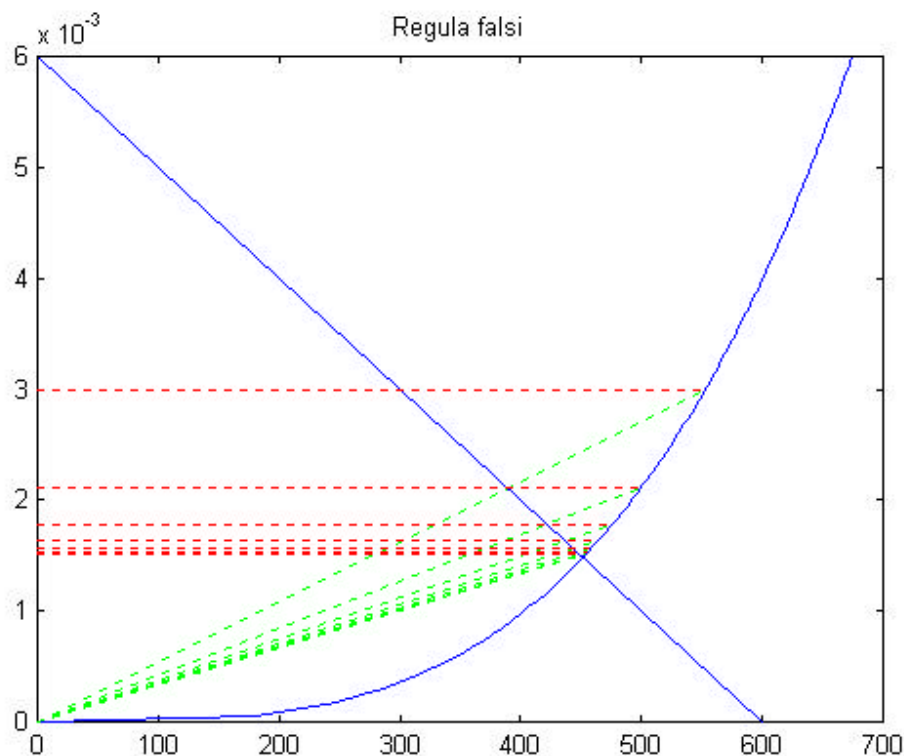


Fig. 4. Iteration process in MATLAB

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