

## Students' interest and performance analysis in power system numerical methods: General function calculation

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### Abstract

Nonlinear equations are the most frequent numerical computation application occurring in scientific investigation or design activity specifically to different branches of power engineering. The objective of this study consisted of the analysis of the interest degree of students towards a specialised subject and the analysis of performance and concentration degree of students in case of solving a laboratory work during the laboratory sessions. Computer program used during laboratory sessions, ECUATIE, contains recent improvements. The first analysis presents the overall situation of student's presences and absences during the laboratory and courses sessions. The second analysis presents the situation of marks obtained following the settlement of laboratory session. Participants are students of Politehnica University Timisoara, Romania. Participants are asked to solve an algebraic or transcendent equation, using different methods. The research found the high degree of student's interest and also the high interest degree of students even if the calculation volume is relatively high.

**Keywords:** Nonlinear equations, numerical coefficients, Newton–Raphson method, false position (chord) method.

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## 1. Introduction

The last decades are characterised by an explosive development of methods and computer engineering, generated by a continued increase in diversity and complexity of the mathematical models, which need to be solved in all branches of science and technology (Thangaraj, 2008, 2013). Power engineering shall be given precedence among the areas with the most spectacular development. It is necessary to solve a wide range of problems in this area. At the regional, zonal, national or multinational level, rational exploitation and management of current power systems put in front of the specialists a number of new issues, whose difficulty is increased by the requirement to address them in real time (Kwan, 2017; Rahimi, Madani & Rahimi, 2016).

Many problems in the energy sector involve in a certain stage, solving linear, algebraic and transcendental equations. For most nonlinear equations, the expression of function  $f(x)$  is complicated, while numerical coefficient values that appear in the expression of  $f(x)$  do not know exactly. Solving numerical equations can be achieved by direct methods (with a finite number of steps or by elementary operations, known from the beginning) or by using 'approximate' iterative numerical methods, with convergence theoretically infinite but practically finite, with permanent estimate of precision degree to determining the solution or solutions (Kilyeni, 2016).

Let consider an equation of the most general form

$$f(x)=0 \quad (1)$$

for which, in most practical application, the definition domain of function  $f(x)$  is a real axis range  $I$ ,  $I \subset \mathfrak{R}$ , and the values domain of  $f$  (co-domain) is  $\mathfrak{R}$ , so  $f: I \rightarrow \mathfrak{R}$  or  $f: \mathfrak{R} \rightarrow \mathfrak{R}$ . If there will appear other situations in definition and function values domains, these will be specified separately.

In the context of practical situations in the electrical engineering field, the problem of solving the nonlinear equation is addressed as follows:

- a) Separation and localisation of equation solutions (1) mean the isolation of subdomains as low range of definition domain  $I$ , which contains one of the zeros of the function  $f(x)$ ;
- b) Determining, with a precision fixed aprioric of a solution, which was isolated in advance, starting from an approximate value of value;
- c) Determining of all solutions, real and complex of equation (1), the problem is usually for algebraic equations.

For each category of problems, it will present the most appropriate algorithms for solving the applications in the power engineering field. Relatively greater attention to methods from b) point pursues the diversification of application for computer program subject.

The national curriculum has experienced numerous transformations, from the classical variant to new innovative variant. The classical variant contains suitable equipment, space and place utilisation and learning resources. At present, we are in the information age. And, according to Geladze (2015) is more important that the information would be accessible and available to everyone. Motivation and student's interest should be maintained by taking account of new factors, leading to new learning forms. These factors refer to informational technology and electronic resources such as simulation software, modern technologies of telecommunications, etc. In the electrical engineering field, the solving of problems must be made through research, experimentation and repetitions. The software tools used in this field are the imitation of real situations. The information is recorded and will be used to study the phenomenon.

Discipline Numerical methods and data structure in power engineering is one of the specialised courses taught in the Department of Electrical Power Engineering of the 'Politehnica' University of Timisoara. The discipline is primarily aimed at familiarising students with numerical algorithms used to solve applications in electrical power engineering domain, correlated with the use of

appropriate computational techniques (Kilyeni, 2016). It contains both algorithms already considered to be classic, and those of a relatively recent date, being focused on understanding mechanistic of numerical methods and data structures, using of them in concrete solving of specialised problems and including transposing them on the computer. The curriculum for this discipline includes theoretical part, presented during class hours and practical application, the latter being divided into laboratory sessions (Kilyeni, Barbulescu & Simo, 2013). Practical applications are designed to be realising in two manners: using specialised computing programs and by manual calculations.

The main objective of this research consists in analysing the degree of interest and performance within the discipline Numerical methods and data structure in power engineering. The first analysis, containing the interest degree, refers to the situation of presences and absences from laboratory and courses sessions. It shows the situation for each student and respectively for each group of students. The performance degree representing the second analysis results from the marks obtained by the students after solving a laboratory paper of the same discipline. The title of the laboratory paper is "Solving the numerical equations."

The practical part will be solved both on the computer and by manual calculation. The theoretical part was presented during hours courses. The evaluation itself, which is the subject of the second analysis, will include manual calculations and calculations using the computer program named ECUATIE. For manual calculations, the following methods are used, namely chord method, Newton–Raphson method and successive approximations method. The authors introduce a new version of ECUATIE computer program recently improved.

## 2. Methods

### 2.1. False position (chord) method

Let us consider the equation form (1), for which the solution was separated in the range  $[a,b]$ . Considering that the function  $f(x)$  is continuous in the range  $[a,b]$ , it is required to determine the solution, accepted errors being function value,  $\varepsilon_f$  and solution,  $\varepsilon_x$ .

Starting from the range  $[a,b]$ , the range of finding the solution is constrained at each step by dividing the interval from the previous step into the ratio of function value to range limits until the desired precision has been reached. Geometrical interpretation of this process is presented in Figure 1. In first step,  $f(x)$  is replaced with string or secant passing through the coordinate points  $(a, f(a))$  and  $(b, f(b))$ . In this case, the equation is defined by relation (2)

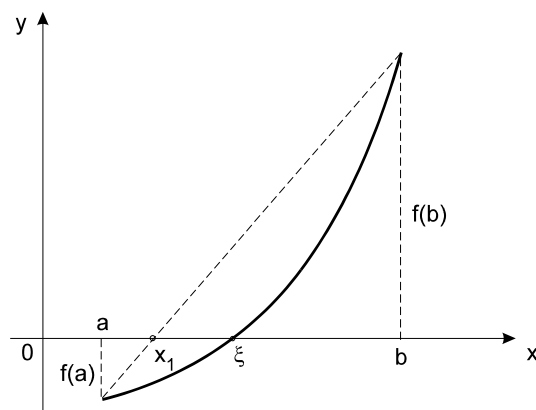


Figure 1. Geometrical interpretation for the false position method (Kilyeni, 2016)

$$\frac{x-a}{b-a} = \frac{f(x)-f(a)}{f(b)-f(a)} \quad (2)$$

resulting in the coordinates of the intersection point between the string and abscissa axis:

$$x = \frac{a \times f(b) - b \times f(a)}{f(b) - f(a)} = a + \frac{f(a)}{f(a) - f(b)} \times (b - a) = b + \frac{f(b)}{f(a) - f(b)} \times (b - a) \quad (3)$$

Under these circumstances, the false position method algorithm is the following:

- a) The limit if the searching current interval is initialised,  $r$  and  $s$ , with the value of interval limits in which the solution is separated;

$$r^0 = a; s^0 = b. \quad (4)$$

- b) At a certain step  $k$ ,  $k = 1, 2, 3, \dots$ , the new value of the solution is calculated.  $f(x^k)$  is determined resulting in the new limits of searching range obtained with relation (6)

$$x^k = \frac{r^{k-1} \times f(s^{k-1}) - s^{k-1} \times f(r^{k-1})}{f(s^{k-1}) - f(r^{k-1})} \quad (5)$$

$$f(x^k) \cdot f(r^{k-1}) \begin{cases} = 0 \Rightarrow \xi = x^k \text{ (finish calculation)} \\ < 0 \Rightarrow r^k = r^{k-1}, s^k = x^k \\ > 0 \Rightarrow r^k = x^k, s^k = s^{k-1} \end{cases} \quad (6)$$

- c) Calculation is considered complete when one of the conditions (7) is satisfied:

$$|x^k - x^{k-1}| \leq \varepsilon_x; |f(x^k)| \leq \varepsilon_f. \quad (7)$$

The second relation (7) ensures the condition  $|x^k - \xi| < \varepsilon_x$  only if  $f'(x)$  is defined, continuous and has constant sign in the range  $[a, b]$ . Otherwise, the range of solution separation must be restricted or additional explorations are necessary.

## 2.2. Newton-Raphson method

Let consider equation form (1), for which the solution was separated in the range  $[a, b]$ . Considering that function  $f(x)$ ,  $f'(x)$  and  $f''(x)$  are continuous in the range  $[a, b]$ , it is required to determine the solution, accepted errors being function value,  $\varepsilon_f$  and solution,  $\varepsilon_x$ . To deduce the relation of recurrence, it is assumed that at the step  $k$  of the iterative process, the final approximate value of solution is  $x^{k-1}$ . A correction of  $h^{k-1}$  added to  $x^{k-1}$  will lead to the exact solution,  $\xi$ :

$$\xi = x^{k-1} + h^{k-1}. \quad (8)$$

Expression (9) results after developing in Taylor series.

$$f(\xi) = 0 = f(x^{k-1} + h^{k-1}) = f(x^{k-1}) + h^{k-1} \times f'(x^{k-1}) + \frac{(h^{k-1})^2}{2!} \times f''(x^{k-1}) + K \quad (9)$$

In relation (9), terms containing  $f(x)$  and  $f'(x)$  are retained and the rest of terms are neglecting. So, the value of  $h^{k-1}$  can be approximate, resulting in a new approximate value of solution  $x^k$ .

$$h^{k-1} = -\frac{f(x^{k-1})}{f'(x^{k-1})} \quad (10)$$

$$x^k = x^{k-1} + h^{k-1} = x^{k-1} - \frac{f(x^{k-1})}{f'(x^{k-1})} \quad (11)$$

Method algorithm is the following:

- a) Solution with value  $x^0$  is initialised;
- b) At a certain step  $k$ ,  $k = 1, 2, 3, \dots$ ,  $f(x^{k-1})$  and  $f'(x^{k-1})$  are calculated, the new value resulting with (10) and (11);
- c) The calculation is considered finished when conditions (12) and (13) are satisfied, or one if them is satisfied.

$$|h^{k-1}| = |x^k - x^{k-1}| \leq \varepsilon_x \quad (12)$$

$$|f(x^k)| \leq \varepsilon_f. \quad (13)$$

### 2.3. Accelerating convergence of successive approximations method

Let us consider equation form (1), for which the solution was separated in the range  $[a, b]$ . Considering that the function  $f(x)$  is continuous in the range  $[a, b]$ , it is required to determine the solution, accepted errors being function value,  $\varepsilon_f$  and solution,  $\varepsilon_x$ . The specific element of this method refers to replacing the implicit classical expression with one equivalent (relation (14)).

$$x = g(x). \quad (14)$$

Method algorithm is the following:

- a) Solution with value  $x^0$  is initialised;
- b) At a certain step  $k$ ,  $k = 1, 2, 3, \dots$ , the new value of solution is calculated with relation (15) and value corresponding to function  $f(x^k)$ ;

$$x^k = g(x^{k-1}). \quad (15)$$

- c) The calculation is considered finished when conditions (16) and (17) are satisfied, or one of them is satisfied.

$$|x^k - x^{k-1}| \leq \varepsilon_x \quad (16)$$

$$|f(x^k)| \leq \varepsilon_f. \quad (17)$$

## 3. Results

The study contains the degree of interest and performance, the conditions in which the computer program used during the laboratory sessions have recently improved. The degree of interest is analysed through the situation of presences and absences from laboratory sessions within the discipline Numerical methods and data structure in power engineering. It shows the situation for each student and respectively for each group of students. Also, the performance degree is the object of the second analysis and includes the marks obtained by the students after solving a laboratory paper of the same discipline. The practical part will be solved both on the computer and by manual calculation. The theoretical part was presented during hours courses. The evaluation itself, which is the subject of the second analysis, will include manual calculations and calculations using the computer program named ECUATIE. For manual calculations, the following methods are used, namely chord method, Newton-Raphson method and successive approximations method.

### 3.1. Participants

The research refers to a case study applied to the second-year students of the Politehnica University Timisoara, Romania in the Department of Electrical Power Engineering. Participants in the

study are 89 students, divided into five groups: 19 students (group 11), 18 students (group 12), 17 students (group 21), 19 students (group 22) and 16 students (group 23). The average age is 20 years.

### 3.2. Instruments

Students use course notes, laboratory tutor, A4 paper, writing instruments and a calculator. Also, the blackboard and calculators are used during the laboratory sessions. Also, a computer program named ECUATIE is used during laboratory sessions.

The computer program was created in Turbo Pascal program. Comparing the previous versions, the last version is ECUATIE program which brings more advantages: graphical interface, working with external files (import and export of data, menu utilisation, command tabs).

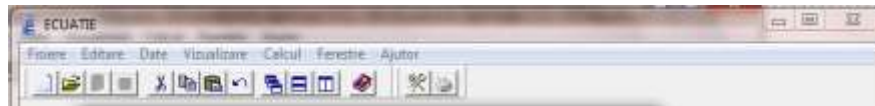


Figure 1. ECUATIE program interface

### 3.3. Question used in research

For the first analysis, the information of detailed record on student's groups during the academic year 2014–2015 is used. For the second analysis, the statement of laboratory paper, mathematical model, solving methods and procedure is presented.

$$f(x) = 0 \quad (18)$$

for which a solution in the range  $[a, b]$  is separated.

It is required to determine with precision a priori imposed the respective solution.

The equation solved will be carried out both by manual calculation and by ECUATION program, using various numerical methods for determining a solution that has previously separated. Thorough, comparative assessment of methods used, it will formulate the obtained results.

To solve numerical equation (2), for a solution determination which was previously located in the range  $[a, b]$ , it will use the following types of methods:

- Range partitioning methods (false position);
- Methods using derivatives of function  $f(x)$  (Newton–Raphson)
- Methods based on explicit expressions equivalent function  $f(x)$  (successive approximations).

Findings result precision will be achieved both through  $x$  variable values at two consecutive iterations and based on  $f(x)$  value at current iteration.

### 3.4. Procedure

The situation of presences and absences was considered for all laboratory and courses sessions. The part of marks obtained after laboratory session in case of paper 'Solving the numerical equations' is presented in the following.

At the beginning of the laboratory session, the teacher will do student's presence and will realise a short review of theoretical concepts presented during hour's course. These notions will be used for laboratory paper.

Paper steps are as follows:

1. Study the text of the paper and numerical methods for solving the equation.
2. Study the tutorial of ECUATIE program.
3. Database for the numerical equation is created and saved.
4. Resolving numerical application using the computer, with all the methods offered by the program, considering  $\varepsilon_x = 10^{-5}$ ,  $\varepsilon_f = 10^{-5}$ , initialising solution making with one of the range limits  $[a, b]$  (same for each method). Solutions and conditions that result are noted (permissible errors, initialisation solution, the number of iterations, etc.).
5. View desktop monitor and study the calculation program ECUATIE. Flowchart is drawn for section refers to solving one method from each category.
6. Solve numerical application by manual calculation with the following methods: false position, Newton–Raphson, accelerating convergence of successive approximations (with errors committed  $\varepsilon_x = 10^{-3}$ ,  $\varepsilon_f = 10^{-3}$ , initialisation solutions where needed and similar to the resolve computer).
7. Comments compared results, making assessments of the methods used. The problem of correlation errors is analysed too.

Students have two laboratory sessions to perform the calculation, each work being for 2 hours.

### 3.5. Resolving numerical application using computer (step 4)

Let consider the transcendent equation defined by relation (19), for which a solution  $\xi$  is separated in the range  $[-1; +1]$ .

$$f(x) = 2 \cdot \operatorname{tg} x - 10 \cdot x + 3 = 0 \quad (19)$$

Considering  $\varepsilon_x = 10^{-5}$  și  $\varepsilon_f = 10^{-5}$ , derivates of  $f(x)$  have expressions defined by relation (20) and explicit expression  $g(x)$  noted with (21).

$$f'(x) = \frac{2}{\cos^2 x} - 10; f''(x) = \frac{4 \cdot \operatorname{tg} x}{\cos^2 x} \quad (20)$$

$$g(x) = 0.2 \cdot \operatorname{tg} x + 0.3 \quad (21)$$

In Table 1 are introduced values of function  $f(x)$  and its derived in considered range. In Figure 2 is presented graph representation of function  $f(x)$  and it's derived.

**Table 1. Values of function  $f(x)$  and its derived**

$x$	$y = f(x)$	$f'(x)$	$f''(x)$	$x$	$y = f(x)$	$f'(x)$	$f''(x)$
-1.0	9.8852	-3.1490	-21.340	0.2	1.4054	-7.9178	0.8442
-0.8	8.9407	-5.8797	-8.4849	0.4	-0.1544	-7.6425	1.9935
-0.6	7.6317	-7.0639	-4.0174	0.6	-1.6317	-7.0639	4.0174
-0.4	6.1544	-7.6425	-1.9935	0.8	-2.9407	-5.8797	8.4849
-0.2	4.5846	-7.9178	-0.8442	1.0	-3.8852	-3.1490	21.340
0.0	3.0000	-8.0000	0.0000				

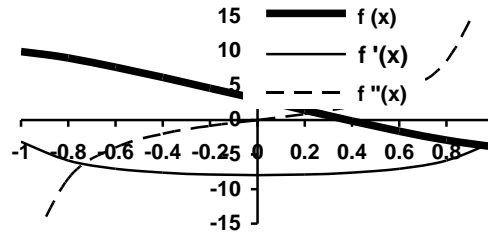


Figure 2. Graph representation of function  $f(x)$  and its derived

The following relations will be calculated in order to decide at which end of the range  $[-1; +1]$  the solution is initialised.

$$f(-1) \cdot f''(-1) = 9.8852 \cdot (-21.34) = -210.95 < 0$$

$$f(1) \cdot f''(1) = -3.8852 \cdot 21.34 = -82.91 < 0.$$

Condition  $f(x) \cdot f''(x) > 0$  is not satisfied for any of the value limit of range. Comparing the two relations, it chooses  $x^0 = 1$ . The results obtained for used methods are presented in Table 2.

Method	$x^0$	Number of iterations	Solution $\xi$	$f(\xi)$	Observations
False position	–	4	0.379847	$-2.91 \times 10^{-11}$	–
Newton–Raphson	1	4	0.379847	0	–
Successive approximations	1	10	0.379847	$-4.01 \times 10^{-6}$	–

The analysis of methods emphasises the following conclusions:

- Due to 'tight' precision imposed, all methods led to the same value of the solution, having six significant digits;
- The convergence to false position method is substantially better;
- For this application, all methods using derivative of  $f(x)$  determine solution in four iterations;
- Studying the value of  $x$  and  $f(x)$  from Table 1, for a good correlation of errors it had to be chosen in ratio  $1/10$ ,  $\varepsilon_f = 10 \cdot \varepsilon_x$ .

### 3.6. Manual calculation with false position method

In this paragraph, a synthesis of manual calculation is presented. The admissible errors are  $\varepsilon_x = 10^{-3}$  and  $\varepsilon_f = 10^{-3}$ . Calculations contain four iterations.

a) Iteration 1

$$x^1 = \frac{-1 \cdot f(1) - 1 \cdot f(-1)}{f(1) - f(-1)} = \frac{-1 \cdot (-3.8852) - 1 \cdot 9.8852}{-3.8852 - 9.8852} = 0.4357$$

$$f(0.4357) = 2 \cdot \text{tg } 0.4357 - 10 \cdot 0.4357 + 3 = -0.4261$$

$$f(0.4357) \cdot f(-1) = -0.4261 \cdot 9.8852 < 0 \Rightarrow r^1 = -1, s^1 = 0.4357.$$

b) Iteration 2

$$x^2 = \frac{-1 \cdot f(0.4357) - 0.4357 \cdot f(-1)}{f(0.4357) - f(-1)} = \frac{-1 \cdot (-0.4261) - 0.4357 \cdot 9.8852}{-0.4261 - 9.8852} = 0.3764$$



$$f(0.3764) = 2 \cdot \operatorname{tg} 0.3764 - 10 \cdot 0.3764 + 3 = 0.0265$$

$$\begin{cases} |f(0.3764)| = 0.0265 > 0.001 \\ |0.3764 - 0.4357| = 0.0593 > 0.001 \end{cases}$$

$$f(0.3764) \cdot f(-1) = 0.0265 \cdot 9.8852 > 0 \Rightarrow r^2 = 0.3764, \quad s^2 = 0.4357.$$

c) Iteration 3

$$x^3 = \frac{0.3764 \cdot (-0.4261) - 0.4357 \cdot 0.0265}{-0.4261 - 0.0265} = 0.3799$$

$$f(0.3799) = 2 \cdot \operatorname{tg} 0.3799 - 10 \cdot 0.3799 + 3 = -0.0004$$

$$\begin{cases} |f(0.3799)| = 0.0004 < 0.001 \\ |0.3799 - 0.3764| = 0.0035 > 0.001 \end{cases}$$

$$f(0.3799) \cdot f(0.3764) = -0.0004 \cdot 0.0265 < 0 \Rightarrow r^3 = 0.3764, \quad s^3 = 0.3799.$$

d) Iteration 4

$$x^4 = \frac{0.3764 \cdot (-0.0004) - 0.3799 \cdot 0.0265}{-0.0004 - 0.0265} = 0.3798$$

$$f(0.3798) = 2 \cdot \operatorname{tg} 0.3798 - 10 \cdot 0.3798 + 3 = 0.0004$$

$$\begin{cases} |f(0.3798)| = 0.0004 < 0.001 \\ |0.3799 - 0.3798| = 0.0001 < 0.001 \end{cases}$$

When comparing the results with those obtained with ECUATIE program, there are minor differences, especially at the last two iterations, due to rounding errors. Manual calculation was performed with 4–5 significant digits, sufficient in relation to errors admitted and variable range and function in the field of interest.

### 3.7. Manual calculation with Newton–Rapson method

In this paragraph, a synthesis of manual calculation is presented. The admissible errors are  $\varepsilon_x = 10^{-3}$  and  $\varepsilon_f = 10^{-3}$ . Calculations contain four iterations. The initialisation of solution is similar to the one solved with ECUATIE program:  $x^0 = 1$ ,  $f(1) = -3,8852$ .

a) Iteration 1

$$f'(1) = \frac{2}{\cos^2(1)} - 10 = -3.1490$$

$$x^1 = 1 - \frac{f(1)}{f'(1)} = 1 - \frac{-3.8852}{-3.1490} = 1 - 1.2338 = -0.2338$$

$$f(-0.2338) = 2 \cdot \operatorname{tg}(-0.2338) - 10 \cdot (-0.2338) + 3 = 4.8617$$

$$\begin{cases} |f(-0.2338)| = 4.8617 > 0.001 \\ |-0.2338 - 1| = 1.2338 > 0.001 \end{cases}$$

b) Iteration 2

$$f'(-0.2338) = \frac{2}{\cos^2(-0.2338)} - 10 = -7.8866$$

$$x^2 = -0.2338 - \frac{f(-0.2338)}{f'(-0.2338)} = -0.2338 - \frac{4.8617}{-7.8866} = -0.2338 + 0.6165 = 0.3827$$

$$f(0.3827) = 2 \cdot \text{tg } 0.3827 - 10 \cdot 0.3827 + 3 = -0.0215$$

$$\begin{cases} |f(0.3827)| = 0.0215 > 0.001 \\ |0.3827 - (-0.2338)| = 0.6165 > 0.001 \end{cases}$$

c) Iteration 3

$$f'(0.3827) = \frac{2}{\cos^2(0.3827)} - 10 = -7.6760$$

$$x^3 = 0.3827 - \frac{f(0.3827)}{f'(0.3827)} = 0.3827 - \frac{-0.0215}{-7.6760} = 0.3827 - 0.0028 = 0.3799$$

$$f(0.3799) = 2 \cdot \text{tg } 0.3799 - 10 \cdot 0.3799 + 3 = -0.0004$$

$$\begin{cases} |f(0.3799)| = 0.0004 < 0.001 \\ |0.3799 - 0.3827| = 0.0028 > 0.001 \end{cases}$$

d) Iteration 4

$$f'(0.3799) = \frac{2}{\cos^2(0.3799)} - 10 = -7.6812$$

$$x^4 = 0.3799 - \frac{f(0.3799)}{f'(0.3799)} = 0.3799 - \frac{-0.0004}{-7.6812} = 0.3799 - 0.0001 = 0.3799$$

$$f(0.3798) = 2 \cdot \text{tg } 0.3798 - 10 \cdot 0.3798 + 3 = 0.0004$$

$$\begin{cases} |f(0.3798)| = 0.0004 < 0.001 \\ |0.3798 - 0.3799| = 0.0001 < 0.001 \end{cases}$$

The differences between values obtained by manual calculation and those determined by ECUATIE program are minor due to rounding errors. Manual calculation was performed only with 4–5 digits. The analysis of the evolution of  $f'(x)$  emphasises an accentuated difference between the value at first iteration and iterations from the following iteration. So, it appears convergence difficulties in applying the simplified version of the Newton method with initialisation  $x^0 = 1$ .

### 3.8. Manual calculation with Successive approximations method

In this paragraph, a synthesis of manual calculation is presented. The admissible errors are  $\varepsilon_x = 10^{-3}$  and  $\varepsilon_f = 10^{-3}$ . Calculations contain five iterations. The initialisation of solution is similar to the one solved with ECUATIE program:  $x^0 = 1$ ,  $f(1) = -3.8852$ . For a better interpretation of the calculation process, in Table 3 are given the values of function  $g(x)$  and its derived in the range  $[-1; +1]$ . All values of  $g'(x)$  are subunit and positive, leading to the conclusion that calculation iterative process will be quasi-monotone convergent.

$$x = 0.2 \cdot \operatorname{tg} x + 0.3$$

$$g'(x) = \frac{0.2}{\cos^2 x}$$

**Table 3. Results for function  $g(x)$  and its derivate**

$x$	$g(x)$	$g'(x)$	$x$	$g(x)$	$g'(x)$
-1.0	-0.0115	0.6851	0.2	0.3405	0.2082
-0.8	0.0941	0.4120	0.4	0.3846	0.2357
-0.6	0.1632	0.2936	0.6	0.4368	0.2936
-0.4	0.2154	0.2357	0.8	0.5059	0.4120
-0.2	0.2595	0.2082	1.0	0.6115	0.6851
0.0	0.3000	0.2000			

a) Iteration 1

$$g(1) = 0.2 \cdot \operatorname{tg}(1) + 0.3 = 0.6115$$

$$\alpha^1 = 1$$

$$x^1 = 1 + 1 \cdot (0.6115 - 1) = 0.6115$$

$$f(0.6115) = 2 \cdot \operatorname{tg}(0.6115) - 10 \cdot (0.6115) + 3 = -1.7126$$

$$\begin{cases} |f(0.6115)| = 1.7126 > 0.001 \\ |0.6115 - 1| = 0.3885 > 0.001 \end{cases}$$

b) Iteration 2

$$g(0.6115) = 0.2 \cdot \operatorname{tg}(0.6115) + 0.3 = 0.4402$$

$$\alpha^2 = \frac{1}{1 - \frac{0.4402 - 0.6115}{0.6115 - 1}} = 1.788$$

$$x^2 = 0.6115 + 1.788 \cdot (0.4402 - 0.6115) = 0.3052$$

$$f(0.3052) = 2 \cdot \operatorname{tg}(0.3052) - 10 \cdot (0.3052) + 3 = 0.5778$$

$$\begin{cases} |f(0.3052)| = 0.5778 > 0.001 \\ |0.3052 - 0.6115| = 0.3063 > 0.001 \end{cases}$$

c) Iteration 3

$$g(0.3052) = 0.2 \cdot \operatorname{tg}(0.3052) + 0.3 = 0.3630$$

$$\alpha^3 = \frac{1}{1 - \frac{0.3630 - 0.4402}{0.3052 - 0.6115}} = 1.337$$

$$x^3 = 0.3052 + 1.337 \cdot (0.3630 - 0.3052) = 0.3825$$

$$f(0.3825) = 2 \cdot \operatorname{tg}(0.3825) - 10 \cdot (0.3825) + 3 = -0.0203$$

$$\begin{cases} |f(0.3825)| = 0.0203 > 0.001 \\ |0.3825 - 0.3052| = 0.0773 > 0.001 \end{cases}$$

d) Iteration 4

$$g(0.3825) = 0.2 \cdot \text{tg}(0.3825) + 0.3 = 0.3805$$

$$\alpha^4 = \frac{1}{1 - \frac{0.3805 - 0.3630}{0.3825 - 0.3052}} = 1.292$$

$$x^4 = 0.3825 + 1.292 \cdot (0.3805 - 0.3825) = 0.3799$$

$$f(0.3799) = 2 \cdot \text{tg}(0.3799) - 10 \cdot (0.3799) + 3 = -0.0004$$

$$\begin{cases} |f(0.3799)| = 0.0004 < 0.001 \\ |0.3799 - 0.3825| = 0.0026 > 0.001 \end{cases}$$

e) Iteration 5

$$g(0.3799) = 0.2 \cdot \text{tg}(0.3799) + 0.3 = 0.3799$$

$$\alpha^5 = \frac{1}{1 - \frac{0.3799 - 0.3805}{0.3799 - 0.3825}} = 1.300$$

$$x^5 = 0.3799 + 1.300 \cdot (0.3799 - 0.3799) = 0.3799$$

$$f(0.3799) = 2 \cdot \text{tg}(0.3799) - 10 \cdot (0.3799) + 3 = -0.0004$$

$$\begin{cases} |f(0.3799)| = 0.0004 < 0.001 \\ |0.3799 - 0.3799| = 0.0000 < 0.001 \end{cases}$$

The same comments are available for this method. First, the differences between values obtained by manual calculation and those determined by ECUATIE program are minor due to rounding errors. Manual calculation was performed only with 4–5 digits. The analysis of the evolution of convergence acceleration,  $\alpha$ , shows that at first iteration its value is 1 and at the last iterations the value is approximately constant (around 1, 3).

#### 4. Discussions

First, the authors analyse the student's degree of interest for the discipline Numerical methods and data structure in power engineering and that their performance following the settlement of laboratory applications related to this discipline. It should be noted that the manner in which the teacher presents the course, laboratory papers and course materials and laboratory tutors itself had a decisive role in obtaining results.

The discipline Numerical methods and data structure in power engineering has 10 laboratory sessions and 10 courses sessions. The situation of student's presences and absences is presented for the five groups. The first two figures (Figures 3 and 4) present the situations of presences and absences at courses and laboratory sessions, in case of student's group 11. The present on courses session is 85% for this student's group. Three students have only four, five and six presents. The present at the laboratory session is about 89% of the total of 10 laboratory sessions. It can be observed that only one student has four absences. This means that the interest of students from this group is higher at laboratory sessions.

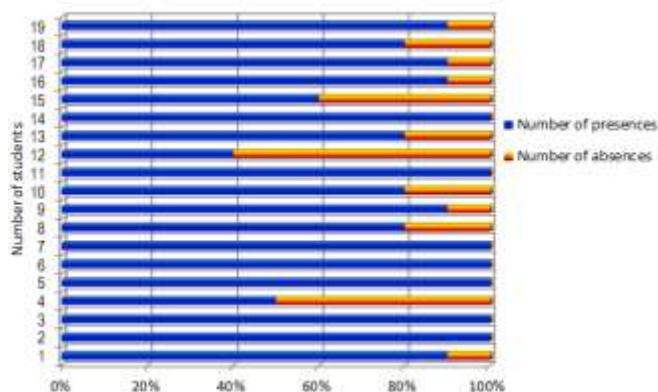


Figure 3. Situation of presences and absences of students from group 11 (Courses sessions)

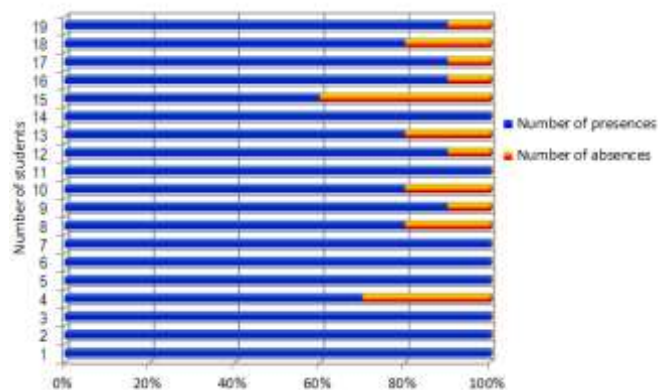


Figure 4. Situation of presences and absences of students from group 11 (Laboratory sessions)

Studying Figures 5 and 6, it shows that six students were not submitted to any course and laboratory session so they did not pass the laboratory related discipline Numerical methods and data structure in power engineering. The presence at course and laboratory session is close as percent: 53% for course sessions and 54% for laboratory sessions. Students' interest from group 12 is smaller than group 11.

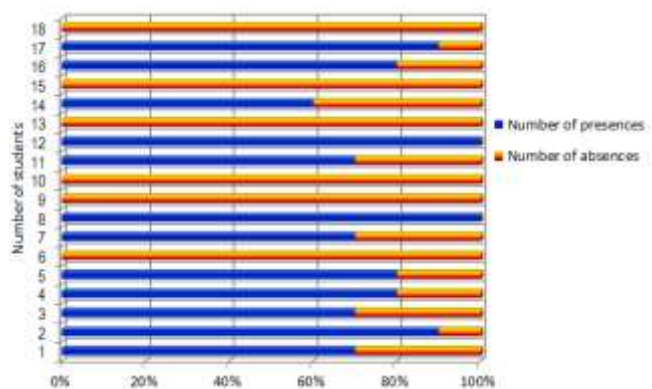


Figure 5. Situation of presences and absences of students from group 12 (Courses sessions)

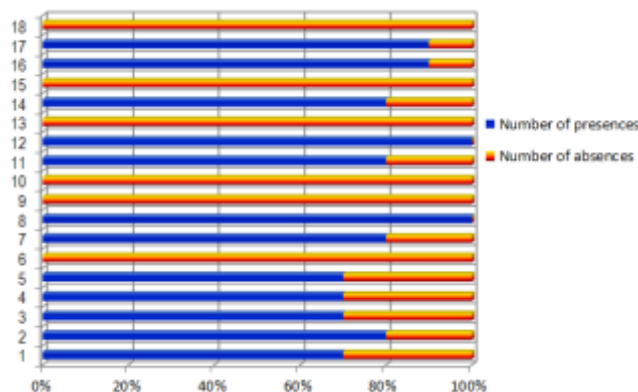


Figure 6. Situation of presences and absences of students from group 12 (Laboratory sessions)

The student's interest level from group 21 differs much than the previous group (Figures 7 and 8). It can be seen that students attended all laboratory sessions, as in the case of group 11. Analysing the problem for the overall group, it finds that group 21 recorded the fewest absences, means 24 absences at course sessions and 16 absences at laboratory sessions. There is one student who has participated in only four laboratory sessions but the presences percentage is 90%.

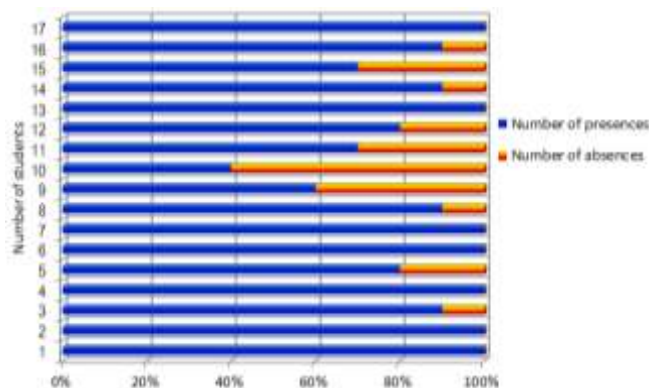


Figure 7. Situation of presences and absences of students from group 21 (Courses sessions)

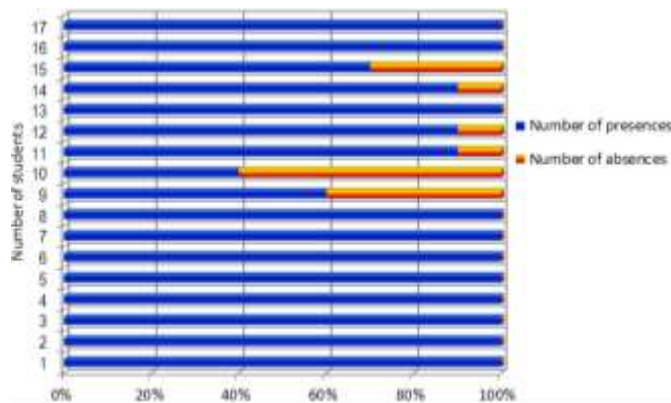


Figure 8. Situation of presences and absences of students from group 21 (Laboratory sessions)

In the case of group 22, the percentage of presences is 0% for three students, while for just four students' percent is 100%. This observation is available both to courses and laboratory sessions. The situation for students' group 22 is presented in Figures 9 and 10. In case of a situation of presences

and absences at laboratory sessions, five students register each 9 presences from 10, while three students were present at all laboratory sessions (Figure 10).

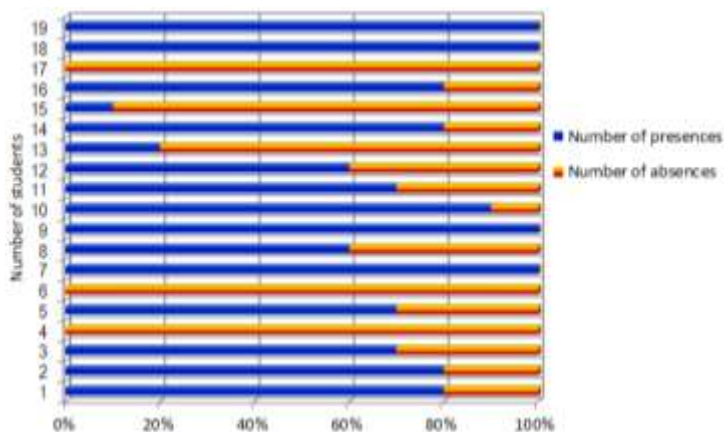


Figure 9. Situation of presences and absences of students from group 22 (Courses sessions)

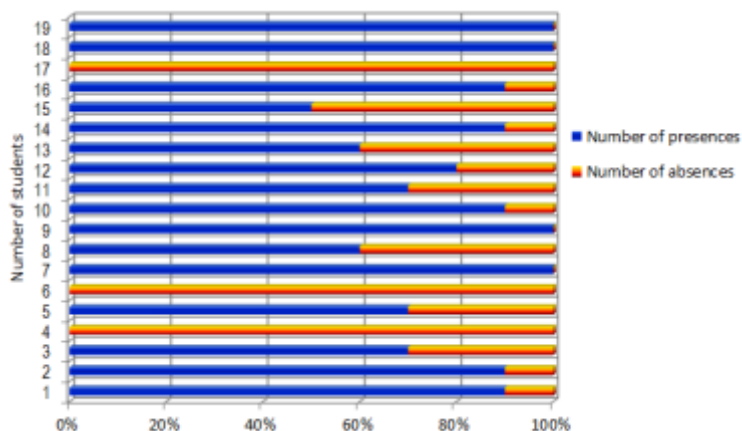


Figure 10. Situation of presences and absences of students from group 22 (Laboratory sessions)

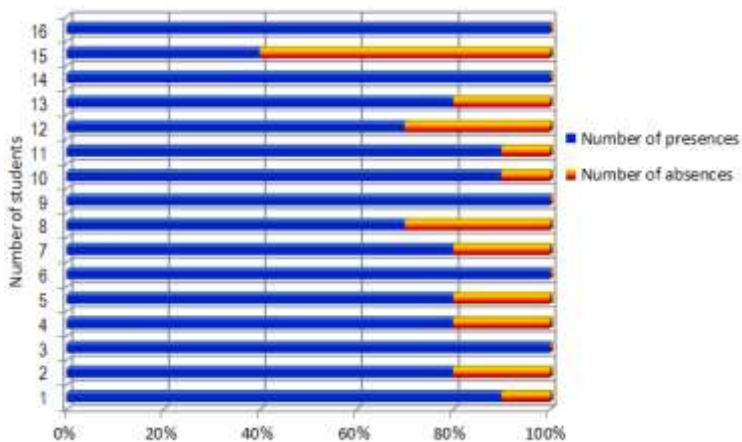
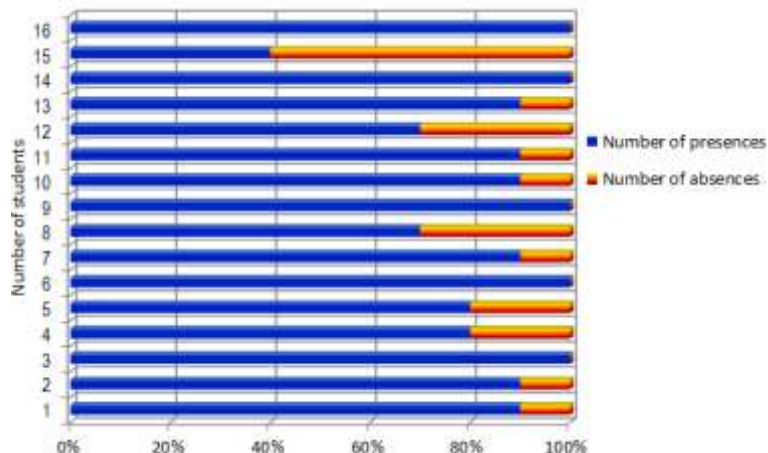


Figure 11. Situation of presences and absences of students from group 23 (Courses sessions)



**Figure 12. Situation of presences and absences of students from group 23 (Laboratory sessions)**

The last analysis contains situation of presences and absences of students from group 23. In Figures 11 and 12 are shown the situation for course sessions and for laboratory session, respectively. This group contains a smaller number of students. Similar to the previous analysis, the high percent of presence on both course and laboratory sessions: 84% and 86%.

The second analysis in this paper is presented in Table 4. The mark is done from note 5 and up to the maximum note 10. Studying the table, the authors found that most students have solved the first five points of paper steps and a part of step 6. It is noted that the laboratory paper is considered completed if all seven points from the course session are settled. Analysing the overall situation, 19 students have solved the application completely, namely five students (Group 11), two students (group 12), three students (group 21), four students (group 22) and five students (group 23). A total of 24 students were able to solve completely first six points and only part of the last point. For mark 6, the authors considered that the first five points are solved. In this regard, it is noted that two students from Group 21 took this mark. It also found that from the total of 80 students, only two students did not pass the laboratory session because they have missed both laboratory sessions.

**Table 4. Students performance**

Obtained mark	Academic year 2014–2015				
	Group 11	Group 12	Group 21	Group 22	Group 23
10	5	2	3	4	5
9	8	4	4	3	5
8	4	5	4	7	2
7	2	1	3	2	3
6	0	0	2	0	0
5	0	0	0	0	0
Unable to solve	0	0	1	0	1
Total	19	12	17	16	16

## 5. Conclusions and recommendations

Numerical methods are very useful in the field of power engineering, especially non-linear, algebraic and transcendental equations. The methods of solving a nonlinear equation are easy to understand but solving by manual calculation requires a large amount of calculation. Therefore, students must present a high degree of concentration.



Referring to these values analysed of presences and absences situation, it can be seen that a large number of students were present in the course and lab sessions. Excepting for students who have not attended any laboratory sessions of course sessions, the highest percentage of absences is properly registered in the case of two students, each with six absences and one with five absences of all 10 laboratory sessions. It means a good interest degree.

From the point of view of solving laboratory applications, it was found that most students have solved at least half of the seven points corresponding to paper steps. Not at last it should be noted that the manner in which the teaching material is structured and presented, has an influence on the performance, interest and understanding the degree of students. Even if students had access to all necessary information for solving all laboratory applications, they are not managed to acquire the same performance. Therefore, it is necessary that they carry out a preliminary reading before the laboratory session.

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