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Using SMATH software for the analysis of steady states in electric circuits

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This paper presents software that can be used for educational purposes – teaching students to perform the analysis of electric circuits [1]. Programmes created in the SMATH system [2] make it possible to solve exercises on electric circuits and constitute an interesting tool supporting the teaching process. The fact that the students can form their own electric circuit structures, with a preview of the equations and the solutions of these calculations, offers to them an interesting learning alternative.

KEYWORDS: electric circuits, computer, SMATH software

1. Introduction

Contemporary computer programmes supporting the analysis of electric and circuits, such as, for instance, PSpice, MATLAB Simulink or TCAD, are an extremely helpful engineering tool. The programmes are also used to teach electrical engineering and electronics basics. However, they do not allow the students to learn the methods of solving electric circuits. The MathCad program is a very good tool for solving electric circuits with the use of classic methods. In this programme formulas are entered in the graphic panel, and the programme does automatic calculations. Coding ability is not required, which is a considerable advantage of the tool. A relatively high price of the MathCad programme is its disadvantage. The SMATH system is an alternative, free programme which is very similar in terms of its application to MathCad. Undoubtedly, its calculation capacity is much smaller in comparison with MathCad, however, it can be successfully used for performing engineering calculations. SMATH can also be used for teaching electrical engineering basics. Students who take the advantage of the ready examples of electric circuits solutions can in a simple way create their own electric circuits models and verify the results of their calculations against numeric results. The programmes developed in the SMATH system make it possible to analyse the methodology of solving electric circuits with the use of various methods (nodal analysis, superposition and similarity method).

2. Electric circuits Analysis in SMATH

This paper presents a number of examples of the SMATH programme application to solve linear electric circuits of direct and alternating current with the use of node voltage analysis method. It describes the method of creating one's own electric circuits scheme with imposed structure, which can be simplified by eliminating selected branches.

2.1. Analysis of direct current steady state

The model of the element Ei (i – element number) of the direct current circuit used in the SMATH programme includes a voltage source Ei, a resistance Ri, a current source Ipi and a resistance Rpi (Fig. 1).

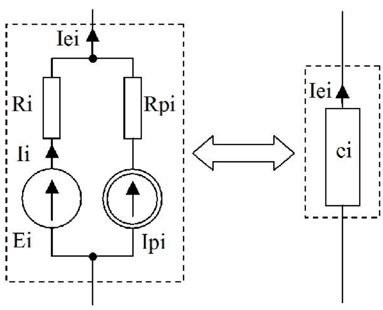

Fig. 1. Model of the direct current circuit element

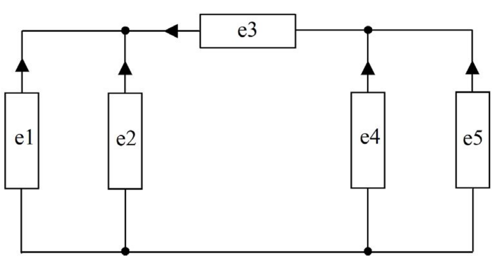

Fig. 2. Structure of a sample electric circuit

The structure of a sample direct current circuit is shown in Fig. 2. In the event when there is only an ideal voltage source for a given branch, the following values should be entered for the remaining elements of the branches: Ipi = 0 A, Rpi = ? (any value can be entered) and Ri = 10^{-4} Ω (four orders smaller value than the lowest resistance in the circuit). If the resistance Ri and the source voltage Ei are not present in the branch model, the following values should be entered: Ri = 10^6 Ω and Ei = 0 V. Figure 3 shows an electric circuit model with the following parameters: E1 = 40 V, R1 = 5 Ω, E2 = 50 V, R2 = 10 Ω, Ip3 = 2 A, R3 = 10 Ω, Ip4 = 0.5 A, E5 = 10 V, R5 = 15 Ω.

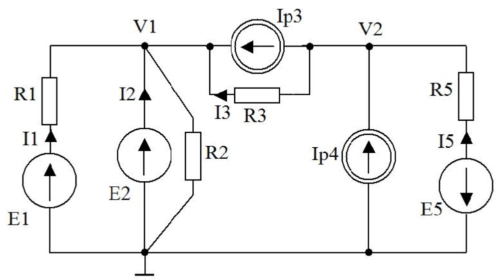

Fig. 3. Direct electric current circuit diagram

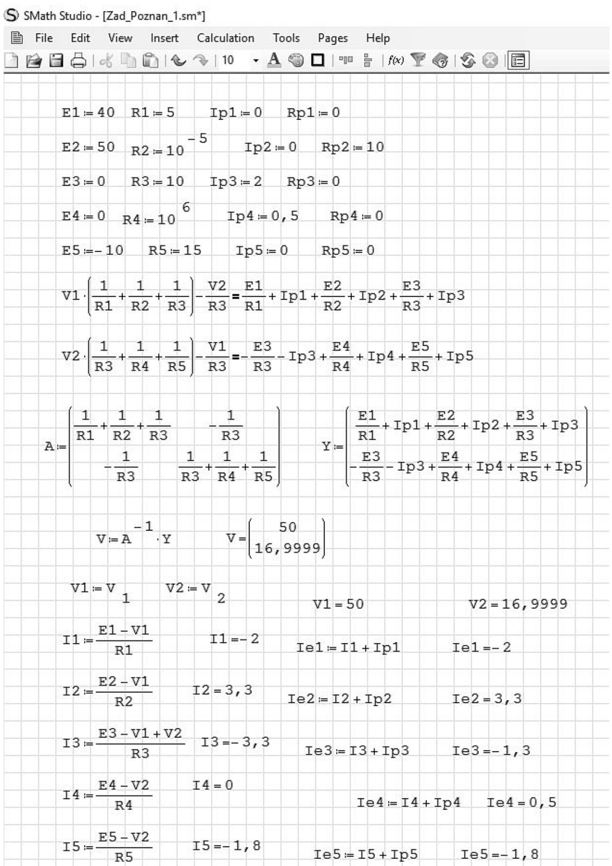

Fig. 4. Programme for the direct current circuit analysis – solution part 1 (Fig. 3)

In order to solve the electric circuit the following values were entered in the SMATH programme (Fig. 4, Fig. 5): E1 = 40 V, R1 = 5 Ω, Ip1 = 0 A, Rp1 = 0 Ω, E2 = 50 V, R2 = 10 Ω, Ip2 = 0 A, Rp2 = 10 Ω, E3 = 0 V, R3 = 10 Ω, Ip3 = 2 A, Rp3 = 0 Ω, E4 = 0 V, R4 = 10^6 Ω, Ip4 = 0.5 A, Rp4 = 0 Ω, E5 = –10 V, R5 = 15 Ω, Ip5 = 0 A, Rp5 = 0 Ω. The user can analyse the method of the circuit solving by following the formulas (Fig. 4, 5) included in the programme and verify his/her own calculations against those delivered by the programme (Fig. 5). In the event when only an ideal voltage source was added in the circuit, then the user solving the formula saves a smaller number of equations. Very low current values below μA should be considered as zero values.

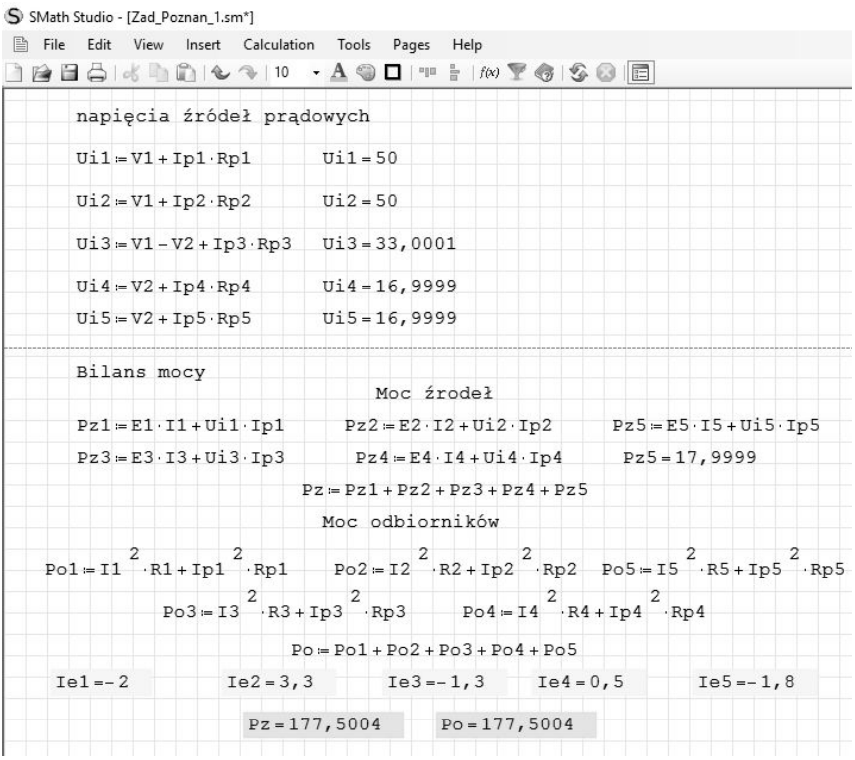

Fig. 5. Programme for the direct current circuit analysis – solution part 2 (Fig. 3)

Figure 6 shows another example of direct current circuit structure. In turn, Fig. 7 shows a circuit diagram with the topology as in Fig. 6, with the following parameters: E1 = 100 V, R1 = 20 Ω, R2 = 10 Ω, Ip3 = 3 A, R3 = 2 Ω, E4 = 40 V R4 = 25 Ω, R5 = 15 Ω, Ip6 = 10 A, R6 = 20 Ω. In order to solve the electric circuit the following values were entered in the SMATH programme:

E1 = 100 V, R1 = 20 Ω, Ip1 = 0 A, Rp1 = 0 Ω, E2 = 0 V, 2 = 10 Ω, Ip2 = 0 A, Rp2 = 0 A, E3 = 0 V, R3 = 10^6 Ω, Ip3 = 3 A, Rp3 = 2 Ω, E4 = 40 V, R4 = 25 Ω, Ip4 = 0 A, Rp4 = 0 Ω, E5 = 0 V, R5 = 15 Ω, Ip5 = 0 A, Rp5 = 0 Ω, E6 = 0 V, R6 = 20 Ω, Ip6 = 10 A, Rp6 = 0 Ω. Figure 8 and Fig. 9 show the solution of the electric circuit from Fig. 7.

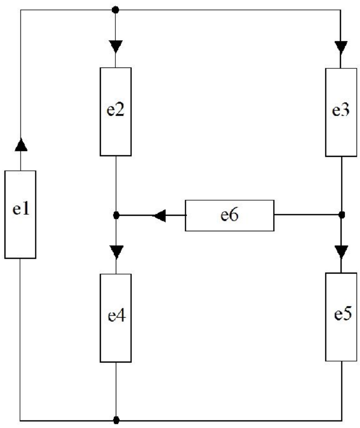

Fig. 6. Topology of a direct current circuit (second example)

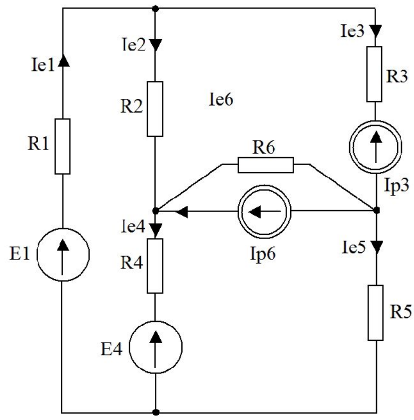

Fig. 7. Direct current circuit diagram (second example)

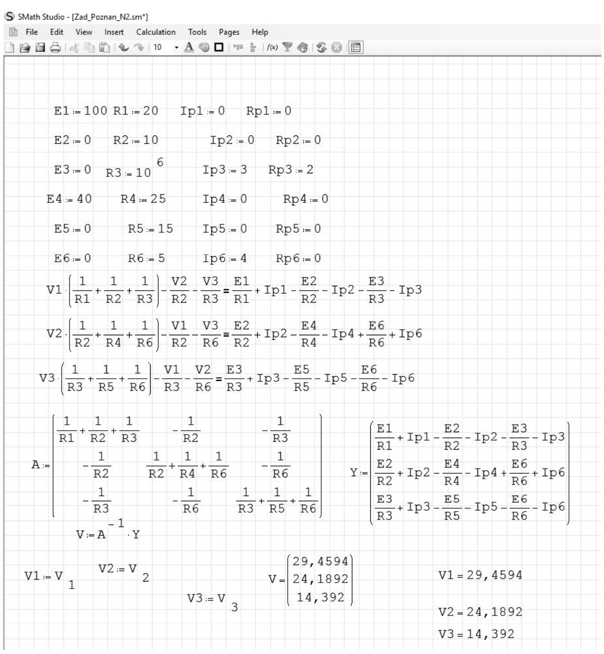

Fig. 8. Programme for the direct current circuit analysis – solution part 1 (example from Fig. 7)

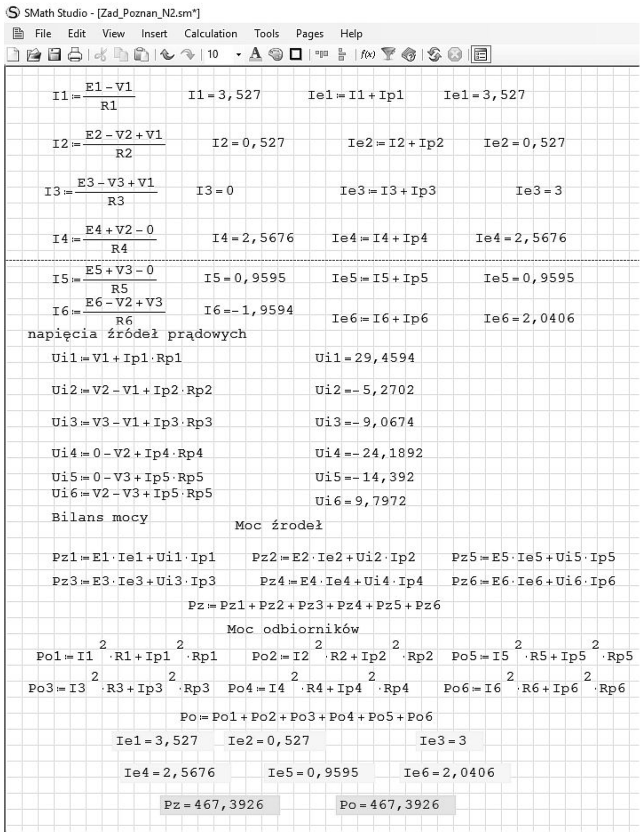

Fig. 9. Programme for the direct current circuit analysis – solution part 2 (example from Fig. 7)

2.2. Analysis of alternating current circuit steady state

It is possible to create numerous combinations of various electric circuits in the analysis alternating current electric circuits, by entering relevant values for particular impedance in the branches.

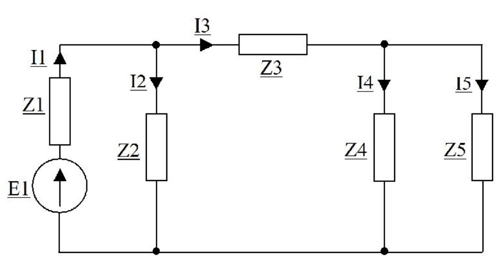

Fig. 10. Structure of a sample alternating current electric circuit

In the case when a given branch is not present in the circuit, a value, e.g. $\underline{Z} = 10^{15}\,\Omega$, should be entered. If the impedance value equals zero, then the value $\underline{Z} = 10^{-6}\,\Omega$ should be entered. Figure 10 presents an alternating current electric circuit diagram. In order to avoid complications while entering data in the SMATH programme, the number and the type of sources were imposed in the circuit. In the example presented in Fig. 11 there is only one voltage source.

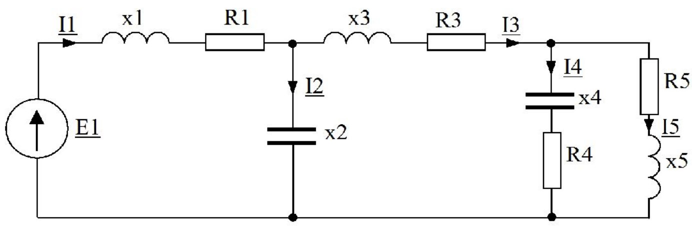

Fig. 11. Alternating current electric circuit diagram

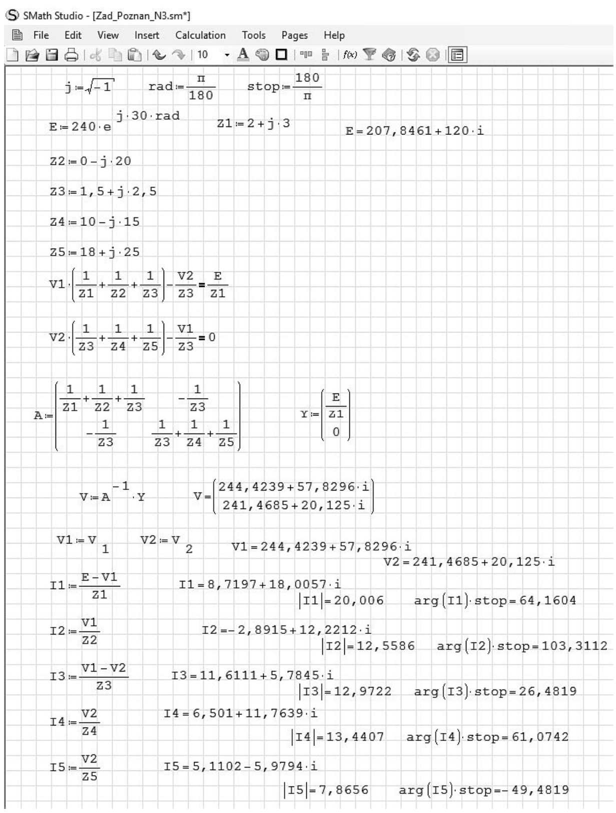

Fig. 12. Programme for the alternating current circuit analysis – solution part 1 (Fig. 11)

Figure 12 and Fig. 13 show an example of a solution for alternating current electric circuit current (Fig. 11) with the following values: $\underline{E} = 240e^{30deg}$ V, R1 =2 Ω, x1 =3 Ω, x2 =20 Ω, R3 =1.5 Ω, x3 =2.5 Ω, x4 =15 Ω, R4 =10 Ω, R5 =18 Ω, x5 =25 Ω.

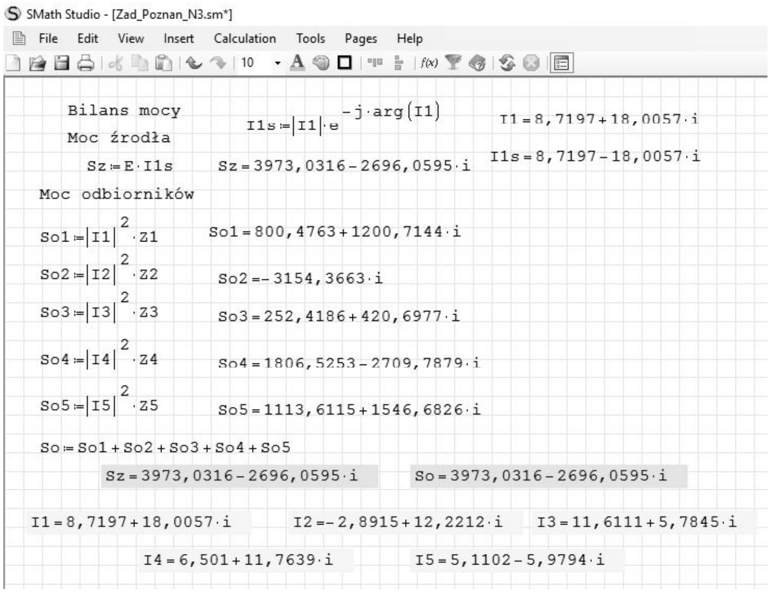

Fig. 13. Programme for the alternating current circuit analysis – solution part 2 (Fig. 11)

In the case when there is a condenser in the branches, a minus value should be entered for the imaginary part of the impedance. For the example presented in Fig. 11 the following data were entered in the programme: $E = 240e^{j30deg}$ V, Z1 = 2+j3 Ω; Z2 = 0–j20 Ω, Z3 = 1,5+j2,5 Ω, Z4 = 10–j15 Ω, Z5 = 18+j25 Ω (in the SMATH programme the underscore is not used in the symbol of the complex number). The programme calculates the current in the branches and the apparent power absorbed by the circuit.

2.3. Analysis of a circuit with magnetic couplings

Figure 14 presents the structure of the alternating current circuit with magnetic couplings. Three coils were added in the circuit with reactance xs1, xs2, xs3, respectively, between which magnetic couplings occur. Magnetic couplings are described by reactance of mutual induction x12, x13 and x23. When in the analysed circuit magnetic coupling does not occur between the coils, in the SMATH programme the value equal to zero for a given magnetic reactance should be entered (x12, x13 or x23). In order to solve a circuit with magnetic coupling between the selected coils opposite to the one assumed in SMATH, the minus value for the magnetic reactance linked to mutual induction should be entered. It is convenient to solve the electric circuit of this type by replacing the subcircuit with magnetically coupled coils with an equivalent subcircuit without couplings [1]. The programme calculates the values of the induction reactance for the subcircuit without couplings, of the current in the branches and the power balance. Figure 15 presents an example of an electric circuit with magnetic couplings with the following parameters: $\underline{E} = 240e^{30deg}$ V, x1 =4 Ω, x3 =23 Ω, R4 = 20 Ω, x5 = 10 Ω, xs1 = 20 Ω, xs2 =12 Ω, x12 = 8 Ω.

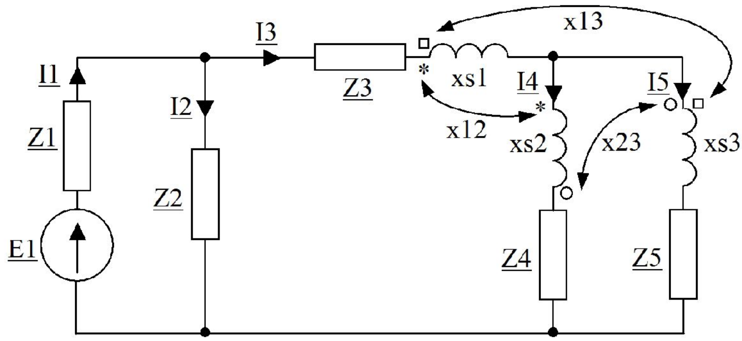

Fig. 14. Structure of a sample alternating current electric circuit with magnetic couplings

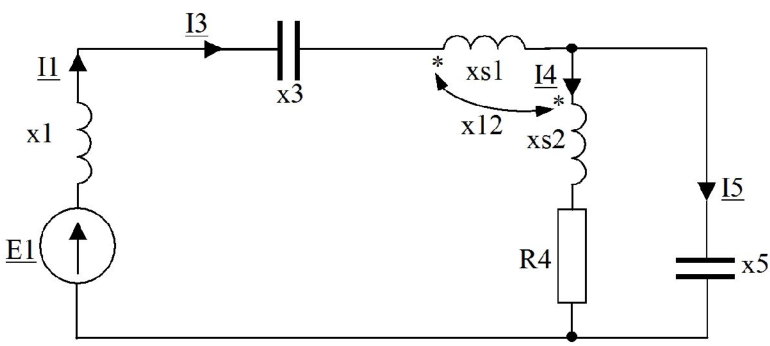

Fig. 15. Diagram of the alternating current electric circuit with magnetic couplings

There is no branch with impedance Z2 in this circuit, whereas impedance Z3 equals zero. In this case in the SMATH programme respective values $\underline{Z2} = 10^{15}$ Ω and $\underline{Z3} = 10^{-6}$ Ω were entered. Figure 16 and Fig. 17 present the results of calculations r in the SMATH programme. The following data were entered in the programme: $E = 240e^{j30deg}$ V, Z1 = 0+j4 Ω; $Z2 = 10^{15}$ Ω, $Z3 = 10^{-4}$–j23 Ω, Z4 = 20–j0 Ω, Z5 = 0–j10 Ω, xs1 = 20 Ω, xs2 = 12 Ω, xs3 = 0 Ω, x12 = 8 Ω, x13 = 0 Ω, x23 = 0 Ω. After an equivalent subcircuit without magnetic couplings is introduced, resonance of voltages can occur in the branches. If such a branch does not include a resistance element, then the programme sends the divide–by–zero error message. In order to ensure the universal character of the programme solving the circuit, additional impedance ZLC = 10^{-6} Ω in each branch with reactance xs1, xs2 and xs3 (Fig. 16) was entered in the equations.

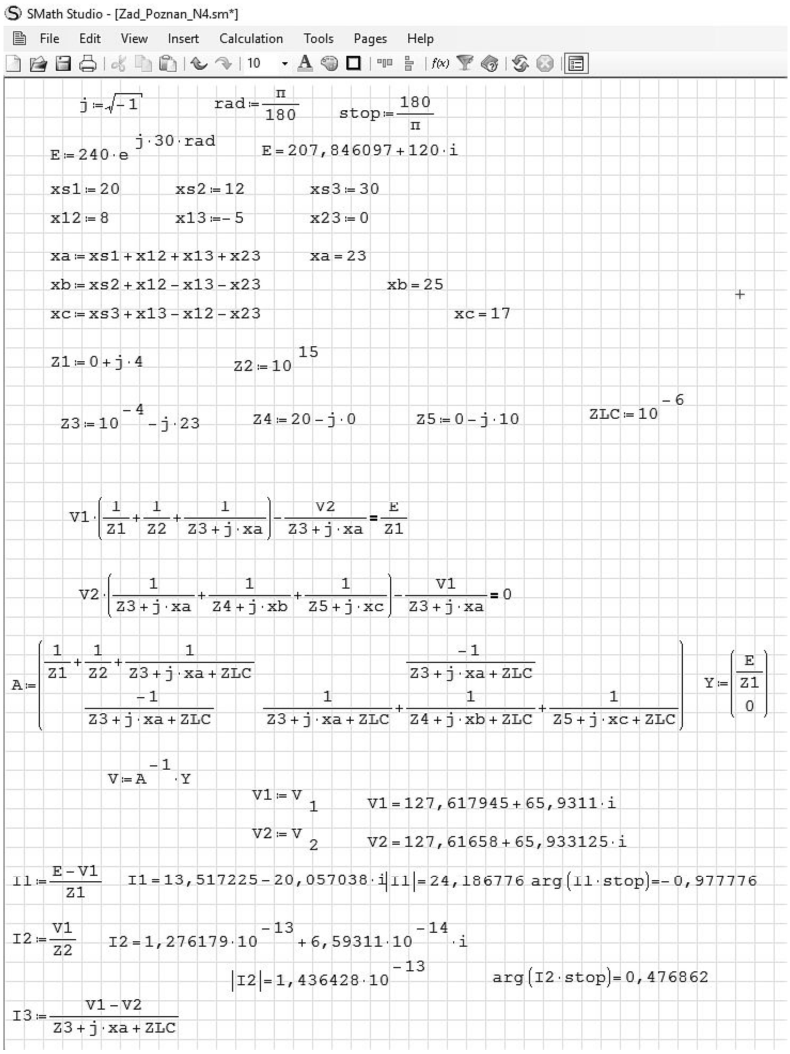

Fig. 16. Programme for the analysis of a circuit with magnetic couplings – part 1 (Fig. 15)

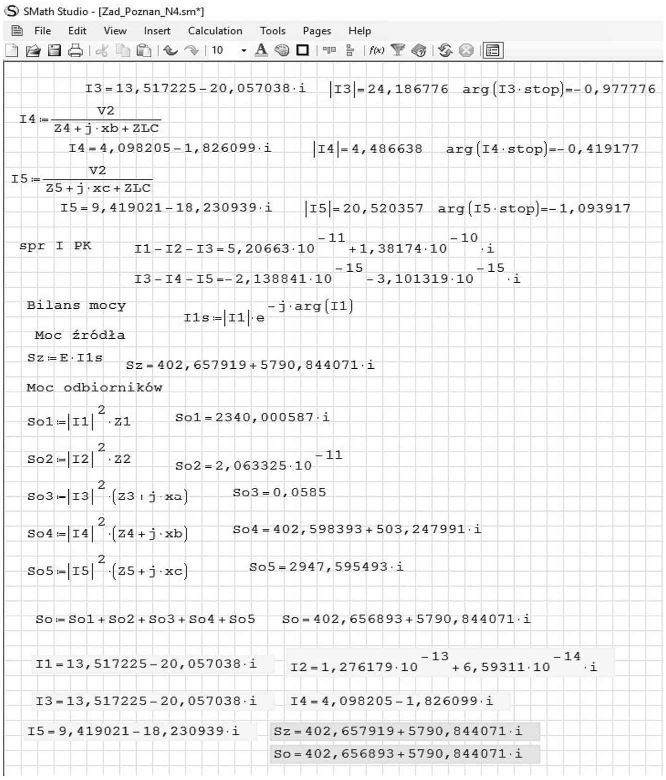

Fig. 17. Programme for the analysis of a circuit with magnetic couplings – part 2 (Fig. 15)

3. Summary

The use of computers in the teaching process allows to improve learning capacity. The SMATH programme is a good educational tool, that helps to teach the students to perform analysis of electric circuits. The user, having numerous programmes developed in SMART at his/her disposal, which make it possible to solve circuits of set topology, has the possibility to create his/her own electric schemes and to verify the results of his/her calculations against numeric results. It is also a highly useful educational tool for the teachers.

References

[1] Bolkowski S., *Elektrotechnika Teoretyczna. Teoria obwodów elektrycznych*, vol. 1, WSiP, Warszawa, 2005, ISBN 978–83–02–09397–5.

[2] www.smath.com

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