DEPARTMENT OF EDUCATION AND SCIENCE OF UKRAINE

NU “ZAPORIZHZHYA POLYTECHNIC”

METHODICAL INSTRUCTIONS

for independent work and implementation of calculation-graphic work in theoretical electrical engineering "The linear circuits of alternating current" for the students of specialty 141

2020

Methodical Instructions for independent work and implementation of calculation-graphic work in theoretical electrical engineering "The linear circuits of alternating current" for the students of specialty 141. //Authors: Kozlov V.V., Nabokova O.V. – Zaporizhzhia: NU “ZAPORIZHZHIA POLYTECHNIC”, 2020. – 22 p.

Authors: V.V. Kozlov, a docent.

O.V. Nabokova, a docent.

Revision of S.V. Voitenko, a lecturer

Responsible for number: O.V. Nabokova, a docent.

Затверджено
на засіданні кафедри ТЗЕ
Протокол №8
від 18.05.2020.

Рекомендовано до видання
НМК Електротехнічного
факультету
Протокол №4
від 25.05.2020

THE CONTENT

1 COMMON INSTRUCTIONS

The theory of the sinusoidal steady-state response of circuits occupies a position of pre-eminence in electric-circuit theory. The analysis of many circuits and devices throughout all branches of electrical engineering is accomplished by the techniques embodied in the sinusoidal theory. In addition to these practical aspects, however, the sinusoidal function offers some very important and significant advantages in a mathematical sense.

One must acquire knowledge of electric circuit analysis, in other words, a proficiency in carrying out a mathematical study of various types of interconnections of electric elements having paths for the flow of electric current. Electric circuit analysis not only aids us in pursuing further studies in electrical engineering but also broadens our scope and helps us to communicate with others involved in a common project (since a specialist invariably becomes a member of a team consisting of other engineers and managers). For a co-ordinate group effort it is important that various members of the group meaningfully communicate with each other.

The purpose of these methodical instructions is to teach the students to do the calculations of any electrical circuit by different methods.

These methods are represented here with the concrete examples of calculation.

The main task of the methodical instructions is to help to the students in using a correspondent method for solving problems of different complication.

The examples considered in data methodical instructions will help to the students to fulfil the necessary calculations and investigations when doing calculation-graphical works prescribed in TBE course.

These methodical instructions include the tasks to design-graphic work (D.G.W.) on calculations methods of alternating current linear circuits.

1.1 The aim and the task of C.G.W.

The aim of this work is to assist students in independent study of suitable parts of theoretical engineering. Students must get practical skills in using the main methods of analysis of alternating current linear electrical circuit.

1.2 Contents and the volume of the work

This design-graphic work consists of the explanatory report with the volume of about 15 pages including figures' graphs and tables.

The contents of the explanatory report:

contents;

a title-page;

a task to calculated-graphic work (C.G.W);

an abstract;

the essence of the explanatory report:

1) explanations to computations and independent calculations;
2) checking up of rightness of the calculations;
3) conclusions;
4) the tasks for protection of this topic
5) appendixes.
6) the list of used original sources;

1.3 The organization and the leadership of C.G.W.

1.3.1 The lecturer is a manager (leader) of C.G.W. He conducts practical lesson on theoretical electrical engineering in the group.

1.3.2 All students' questions on using, checking and designing this C.G.W. must be decided at the weekly teacher's consultations according to teacher's time-table.

1.4 Designing and presenting C.G.W.

One must carry out the following requirements:

1.4.1 The explanatory report must be designed according to the requirements of the Ukrainian State Standard;

1.4.2. The possible errors of the calculations should be within no more than 3%.

1.4.3. The assignment issued to students is considered to be completed only after the lecturer has checked it and then defended both the solved assignment and this topic as a whole.

2 THE TECHNICAL TASK TO C.G.W

2.1 Every student has to do his own assignment. The number of his assignment equals the number of student's surname in a group register.

2.2 Part I. The proposed electrical circuit works when a variable sinusoidal voltage is applied to the input terminals. An instantaneous voltage $u = U_m(\sin\omega t + \varphi)$, with the frequency of variable voltage $f = 50 Hz$ is applied to the circuit. There is no mutual inductance here.

2.2.1 Calculate currents and voltages in all the branches of this electrical circuit.

2.2.2 Draw a combined vector diagram of currents and voltages.

2.2.3 Compile the balance of active and reactive powers.

2.2.4 Consider the branches which resonance of voltages or currents may be in and determine the resonance frequency.

2.4 Part II. The same electrical circuit but with mutual connection between two coils works when a variable sinusoidal voltage is applied to the input terminals. An instantaneous voltage $u = U_m(\sin\omega t + \varphi)$, $f = 50\ Hz$ and the coefficient of mutual inductance $M = 63.7$ mH. The mutual connection in branches is given by a lecturer for every variant.

2.4.1 Define the complex currents and voltages for all branches.

2.4.2 Draw a vector diagram for the values of currents and voltages including the values of magnetic voltages.

2.4.3 Write the expressions for instantaneous meanings of found currents and voltages.

2.4.4 Define the values of complex powers for all the branches.

2.4.5 Define the active power to be transmitted from the branch to another one with the help of mutual inductance.

2.2.5 Write down the conclusions after fulfilling this work.

2.5 An example of calculation of composed circuit without a mutual inductance is given in Appendix A

2.6 The values of passive elements, voltage and current resources are given in appendix B.

2.7 The diagrams of electrical circuits are given in appendix C.

3 THE INSTRUCTIONS ON USING THE WORK

3.1 The symbolic method of calculation of alternating current linear electrical circuits (without of mutual connection).

Alternating current circuit problems are most often solved by the symbolic method. The basis of this method is that for a sinusoidal varying current the equations based on instantaneous values, which are in fact differential equations, may be replaced by algebraic equations in complex currents and voltages.

More specifically, in any Kirchhoffian equation written for the steady-state, the instantaneous currents and voltages are replaced by their effective values.

This method is used for the facilitation of calculation of alternating current circuits with any character of load.

Active and passive cells of the electrical circuit have such forms:

a) sinusoidal electro-motion force (E.M.F.), voltage and current

$$e = E_m \sin(\omega t + \varphi_e)$$

$$u = U_m \sin(\omega t + \varphi_u)$$

$$i = I_m \sin(\omega t + \varphi_i)$$

b) complex values of E.M.F., voltage and current

$$\dot{E} = Ee^{j\varphi_e}; \quad \dot{U} = Ue^{j\varphi_u}; \quad \dot{I} = Ie^{j\varphi_i}$$

where $E = \dfrac{E_m}{\sqrt{2}}$ - the effective value of sinusoidal electromotive force;

$U = \dfrac{U_m}{\sqrt{2}}$ - the effective value of sinusoidal voltage;

$I = \dfrac{I_m}{\sqrt{2}}$ - the effective value of sinusoidal current;

c) complex impedances

$$\underline{Z} = \underline{Z}e^{\pm j\varphi} = \underline{Z}\cos\varphi \pm j\underline{Z}\sin\varphi = R \pm jX$$

where "plus" sign before reactance corresponds to the inductive load and "minus" sign corresponds to the capacity load.

d) complex powers: active, reactive and apparent (total)

$P = \mathrm{Re}\left(\dot{U}\dot{I}^*\right)$; $Q = \mathrm{Im}\left(\dot{U}\dot{I}^*\right)$; $S = \dot{U}\dot{I}^*$

where P – is the active or true power;

Q - is the reactive power;

S - a complex of total (apparent) power;

Re – the real part of a complex number;

Im – an imaginary part of a complex number;

$\dot{I}^*$ - a conjugate complex current.

So, the complex-number method is called the symbolic method for the reason that the currents and voltages are represented by their complex transforms or symbols.

Current flow through the passive elements results in some energy is dissipation. On the basis of the law of conservation of energy, this dissipated energy to be made up for if a given circuit is to perform its function.

In other words, the rate of energy input in alternating current circuit must be equal to the rate of energy dissipation by that circuit.

The balance of powers in symbolic form

$$\sum_{k=1}^{n} \underline{Z}_k I_k^{\ 2} = \sum_{k=1}^{n} \dot{E}_k I_k$$

Ohm's Law for a part of the circuit with the source of Electro-motive force (EMF):

$$\dot{I} = \frac{\dot{U} \pm \dot{E}}{\underline{Z}} = \frac{\dot{U} \pm \dot{E}}{R + j\left(X_L - X_C\right)}$$

Write Kirchhoff's voltage law for effective values (see fig.3.1):

$$\dot{U} = \dot{I}\,\underline{Z} = \dot{I}\left(R + j\omega L + \frac{1}{j\omega C}\right)$$

Then the magnitude of the effective current is

$$\dot{I} = \frac{\dot{U}}{R + j\omega L + \frac{1}{j\omega C}} = \frac{\dot{U}}{R + j\left(X_L - X_C\right)}$$

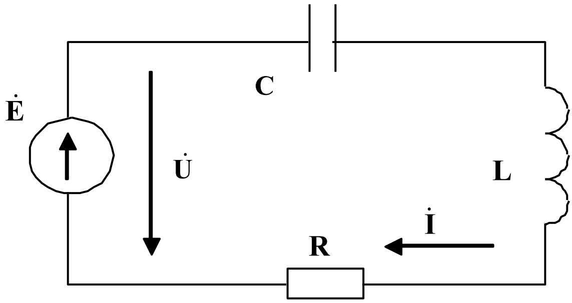


Figure 3.1 - The series RLC circuit

On defining the values of all the currents and voltages one must draw a vector diagram for the circuit. A vector diagram is a graphic representation of the vectors of sinusoidal quantities in a complex plane. The quantities are taken all at the same frequency and in proper phase relationship with respect to one another.

As a rule, the currents and voltages of the various portions of a sinusoidal circuit are not in phase. Their phase relationships can be visualized by use of current and voltage vector diagrams. That is why it will be good practice to follow up analytical network calculations with vector diagrams as a qualitative check on the analytical results.

The qualitative check provided by vector diagram consists in that the various vectors in the complex plane yielded by analytical calculations can be compared for their directions with those obtained graphically from purely physical considerations.

Thus, in a vector diagram the complex voltage $\dot{U}_L$ across an inductance should lead the current through it by 90^o, while the complex voltage $\dot{\mathbf{U}}_\mathbf{C}$ across a capacitance should lag behind the current through it by 90^o. Should analytical calculations yield results which disagree with such obvious observations, there is a mistake in the calculation, which should be traced down and eliminated.

The vector diagram for such a current (when $X_L > X_C$) is shown in Fig.3.2.

The voltage across the capacitor terminal $\dot{\mathbf{U}}_\mathbf{C}$ is represented by line "**ab** ". Current $\dot{\mathbf{I}}$ leads capacitor voltage $\dot{\mathbf{U}}_\mathbf{C}$ by $\mathbf{90^o}$. The voltage drop across the resistor terminal $\dot{U}_R$ must be in phase with $\dot{I}$ because they coincide through an active resistance. It is represented by line "bc", which is parallel to the current $\dot{I}$ .The line "cd" represents the effective voltage across the inductor terminal $\dot{U}_L$.

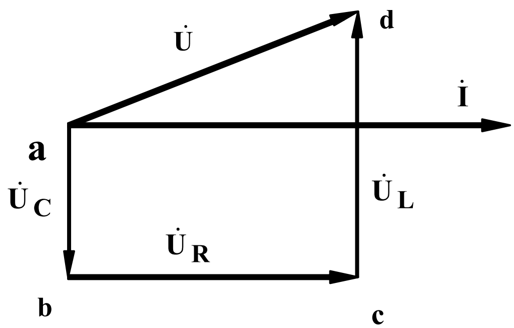


Figure 3.2 - Phasor diagram of the RLC circuit for $X_L > X_C$

The phasor sum of three voltage drops $\dot{U}_C$, $\dot{U}_R$ and $\dot{U}_L$ gives us the applied voltage $\dot{U}$ – line "ad".

The application of the theory is best illustrated by the calculated example in appendix A.

3.2 The symbolic method of calculation of a.c. electrical circuit with a mutual inductance

If an electric circuit contains a mutual inductance (that is, magnetically coupled coils), the flux due to one links the other, and there is an e.m.f. of mutual inductance in each coil that must be taken into account.

When we need calculate a circuit with mutual inductance we put into operation the conception of the impedance of mutual inductance $\underline{Z}_m = j\omega M$, where M is said to be the coefficient of mutual inductance between two inductors.

When we have two coils with mutual connection we must compare the direction of summation round the contour with the direction of the current in an inductance-connected coil.

If they coincide in directions we will have the voltage of mutual induction (or the mutual e.m.f.) with "plus" sign. If they have the opposite directions the voltage of mutual induction will be negative.

The voltage of mutual induction for the first coil is

$$\dot{U}_{1m} = \underline{Z}_m \dot{I}_2$$

The voltage of mutual inductance for the second coil is

$$\dot{U}_{2m} = \underline{Z}_m \dot{I}_1$$

The power to be transmitted from the first coil to another one and vice versa by an electromagnetic field is

$$P_{1m} = \mathrm{Re}\left(\dot{U}_{1m} \cdot \dot{I}_1^{\,*}\right) = P_{2m} = -\,\mathrm{Re}\left(\dot{U}_{2m} \cdot \dot{I}_2^{\,*}\right)$$

Hence we can write equations for calculation the circuit (Fig.3.3) with mutual inductance.

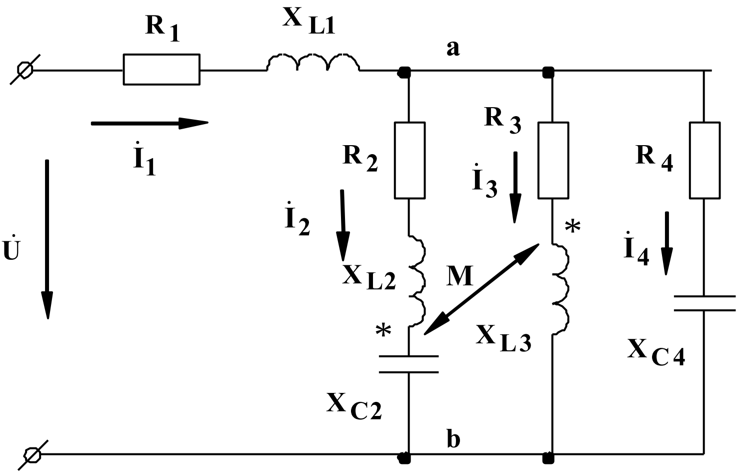


Figure 3.3 - A.c. circuit with mutual inductance

The values of branch's impedances have the following values

$$\underline{Z}_1 = R_1 + jX_{L1}$$

$$\underline{Z}_2 = R_2 + j(X_{L2} - X_{C2}) \qquad (3.12)$$

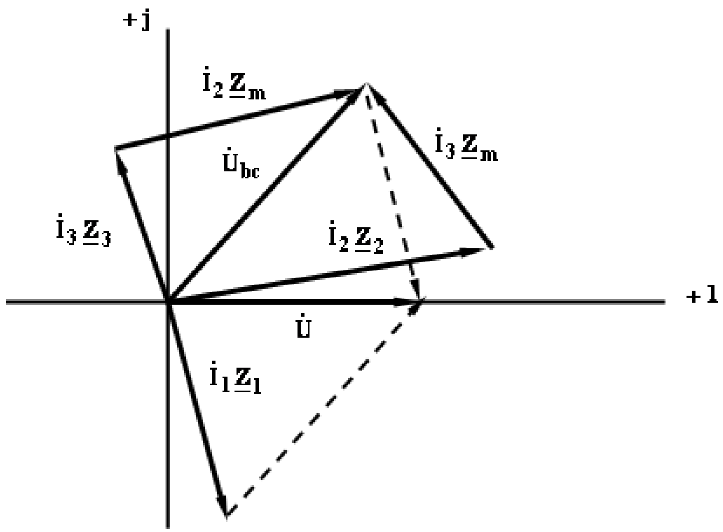
$$\underline{Z}_3 = R_3 + jX_{L3}$$

$$\underline{Z}_4 = R_4 - jX_{C4}$$

According to Kirchhoff's current and voltage laws we have such equations for this circuit

$$\dot{I}_1 - \dot{I}_2 - \dot{I}_3 - \dot{I}_4 = 0$$
$$\underline{Z}_1\dot{I}_1 + \underline{Z}_2\dot{I}_2 - \underline{Z}_m\dot{I}_3 = \dot{U}$$
$$\underline{Z}_3\dot{I}_3 - \underline{Z}_2\dot{I}_2 - \underline{Z}_m\dot{I}_2 + \underline{Z}_m\dot{I}_3 = 0$$
$$\underline{Z}_3\dot{I}_3 - \underline{Z}_4\dot{I}_4 + \underline{Z}_m\dot{I}_2 = 0$$

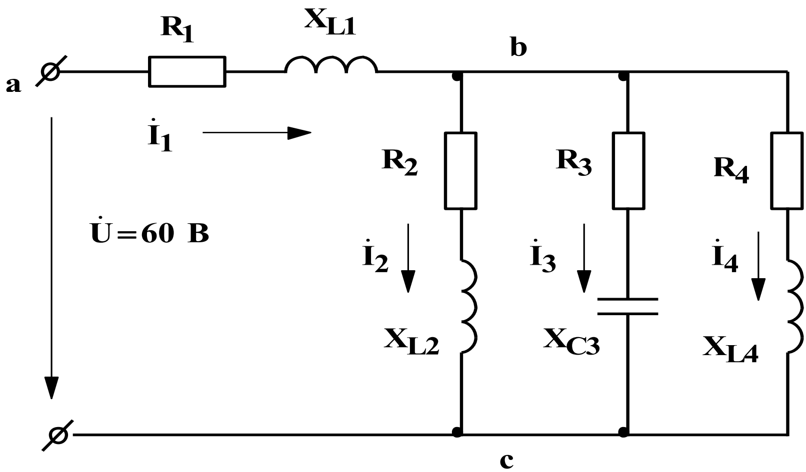
These equations can be calculated with the help of computer in any ways. So students can use ready-made computer programs for calculating circuits of alternating sinusoidal alternating current. On having got the values of all the currents and voltages one must draw a vector diagram for this circuit. So, we can see approximately such a vector diagram for voltages in the next figure.



The data for calculation are given in appendix B.

The diagrams of electrical circuit for calculation are given in appendix C.

Appendix A An example of calculation of composed circuit without a mutual inductance



Data for calculation: $\dot{U} = 60\ V$; $f = 50\ Hz$;

$R_1 = 10\ \Omega$; $R_2 = 15\ \Omega$;

$R_3 = 3\ \Omega$; $R_4 = 8\ \Omega$;

$L_1 = 31.85 \cdot 10^{-3}\ H$;

$L_2 = 63.7 \cdot 10^{-3}\ H$;

$L_4 = 19 \cdot 10^{-3}\ H$;

$C_3 = 79.62 \cdot 10^{-3}\ mF$.

Knowing the values of capacity and inductance we can find at first inductive and capacity reactances:

$$X_{L1} = \omega L_1 = 2\pi f L_1 = 314 \cdot 31.85 \cdot 10^{-3} = 10\ \Omega$$

$$X_{L2} = \omega L_2 = 2\pi f L_2 = 314 \cdot 63.7 \cdot 10^{-3} = 20\ \Omega$$

$$X_{C3} = \frac{1}{\omega C_3} = \frac{1}{2\pi f C_3} = \frac{1}{314 \cdot 79.62 \cdot 10^{-3}} = 4\ \Omega$$

$$X_{L4} = \omega L_4 = 2\pi f L_4 = 314 \cdot 19 \cdot 10^{-3} = 8\ \Omega$$

The impedances have the following values:

$$\underline{Z}_1 = R_1 + jX_{L1} = 10 + j10 = 14.14e^{j45^o}\ \Omega$$

$$\underline{Z}_2 = R_2 + jX_{L2} = 15 + j20 = 25.0e^{j53^o}\ \Omega$$

$$\underline{Z}_3 = R_3 + jX_{C3} = 3 - j4.0 = 5.0e^{j-53^o}\ \Omega$$

$$\underline{Z}_4 = R_4 + jX_{L4} = 8 + j6.0 = 10.0e^{j37^o}\ \Omega$$

Because there are more than two impedances in parallel between terminals b and c it is simpler to work first in terms of the admittance of the parallel combinations. Thus

$$\underline{Y}_{bc} = \frac{1}{\underline{Z}_{bc}} = \frac{1}{\underline{Z}_2} + \frac{1}{\underline{Z}_3} + \frac{1}{\underline{Z}_4} = \frac{1}{15 + j20} + \frac{1}{3 - j4} + \frac{1}{8 + j6} =$$

$$= 0.224 + j0.068 = 0.234e^{j17^o}\ Sm$$

Then complex impedance can be found as inverse value to the complex admittance

$$\underline{Z}_{bc} = \frac{1}{\underline{Y}_{bc}} = \frac{1}{0.234e^{j17^o}} = 4.27e^{-j17^o} = 4.09 - j1.24\ \Omega$$

The equivalent total impedance between **a** and **c** is then given by

$$\underline{Z}_e = \underline{Z}_{ac} = \underline{Z}_1 + \underline{Z}_{bc} = 10 + j10 + 4.09 - j1.24 =$$

$$= 14.09 + j8.76 = 16.2e^{j32^o}\ Ohm$$

After transformation of the circuit this equivalent impedance is connected in series to the voltage source. That is why we can find a total current in the circuit according to Ohm's law

$$\dot{I}_1 = \frac{\dot{U}}{\underline{Z}_{ac}} = \frac{60e^{j0^o}}{16.2e^{j32^o}} = 3.70e^{-j32^o}\ A$$

Hence the voltage between points **b** and **c** is

$$\dot{U}_{bc} = \dot{I}_1 \underline{Z}_{bc}$$

$$\dot{U}_{bc} = \dot{I}_1 \underline{Z}_{bc} = 3.70e^{-j32^o} \cdot 4.27e^{-j17^o} = 15.82e^{-j49^o} =$$

$$= 10 - j11.9\ V$$

Now one can calculate currents in parallel branches by Ohm's Law for the part of the circuit

$$\dot{I}_2 = \frac{\dot{U}_{bc}}{\underline{Z}_2} = \frac{15.82e^{-j49^o}}{25.0e^{j53^o}} = 0.633e^{-j102^o}\ A$$

$$\dot{I}_3 = \frac{\dot{U}_{bc}}{\underline{Z}_3} = \frac{15.82e^{-j49^o}}{5.0e^{-j53^o}} = 3.163e^{j4^o}\ A$$

$$\dot{I}_4 = \frac{\dot{U}_{bc}}{\underline{Z}4} = \frac{15.82e^{-j49^o}}{10.0e^{j37^o}} = 1.582e^{-j86^o}\ A$$

Calculate the voltage drop on non-ramified part of the circuit

$$\dot{U}_1 = \dot{I}_1\underline{Z}_{b1} = 3.7e^{-j32^o} \cdot 14.14e^{j45^o} = 52.33e^{j13^o} = 50.6 + j11.8\ V$$

Check up the result of calculations composed the equation for the first contour with the help of Kirchhoff's voltage law

$$\dot{U} = \dot{U}_1 + \dot{U}_{bc} = 50.6 + j11.8 + 10 - j11.9 = 60.6 - j0.1 \approx 60.6\ V$$

Small discrepancy in values of given and calculated voltages is explained by the inaccuracy of calculations.

Compile the balance of active and reactive powers.

The energy that the source can deliver to the load must be equal to the energy that is dissipated in the elements of the circuit.

The active powers in branches:

$$P_1 = R_1 \cdot I_1^{\ 2} = 10 \cdot 3.7^2 = 136.9\ Wt$$

$$P_2 = R_2 \cdot I_2^{\ 2} = 15 \cdot 0.633^2 = 6.01\ Wt$$

$$P_3 = R_3 \cdot I_3^{\ 2} = 3 \cdot 3.163^2 = 30.01\ Wt$$

$$P_4 = R_4 \cdot I_4^{\ 2} = 8 \cdot 1.582^2 = 20.02\ Wt$$

The common active power

$$P = P_1 + P_2 + P_3 + P_4$$

$$P = 136.9 + 6.01 + 30.01 + 20.02 = 192.94\ Wt$$

The reactive powers in branches:

$$Q_1 = X_1 \cdot I_1{}^2 = 10 \cdot 3.7^2 = 136.9\ VAr$$

$$Q_2 = X_2 \cdot I_2{}^2 = 20 \cdot 0.633^2 = 8.01\ VAr$$

$$Q_3 = -X_3 \cdot I_3{}^2 = -4 \cdot 3.163^2 = -40.02\ VAr$$

$$Q_4 = X_4 \cdot I_4{}^2 = 6 \cdot 1.582^2 = 15.02\ VAr$$

The common reactive power

$$Q = Q_1 + Q_2 + Q_3 + Q_4$$

$$Q = 136.9 + 8.01 - 40.02 + 15.02 = 119.91\ Wt$$

The apparent power

$$S = \sqrt{P^2 + Q^2} = \sqrt{192.94^2 + 119.91^2} = 224.2\ VA$$

The complex apparent power is obtained if the complex voltage is multiplied by the conjugate of the complex current

$$\tilde{S} = UI_1^* = 60 \cdot 3.7e^{j32^o} = 222e^{j32^o}$$

Consider the third and the fourth parallel branches where the resonance may occur and define the resonance frequency. The condition of current resonance is $B_L = B_C$ from where we can define ω :

$$\omega = \frac{1}{\sqrt{L_4 C_3}} \cdot \sqrt{\frac{\frac{L_4}{C_3} - R_4{}^2}{\frac{L_4}{C_3} - R_3{}^2}} =$$

$$= \frac{1}{\sqrt{19 \cdot 10^{-3} \cdot 79.62 \cdot 10^{-3}}} \cdot \sqrt{\frac{\frac{19 \cdot 10^{-3}}{79.62 \cdot 10^{-3}} - 8^2}{\frac{19 \cdot 10^{-3}}{79.62 \cdot 10^{-3}} - 3^2}} =$$

$$= 25.71 \cdot \sqrt{7.28} = 69.4\ s^{-1}$$

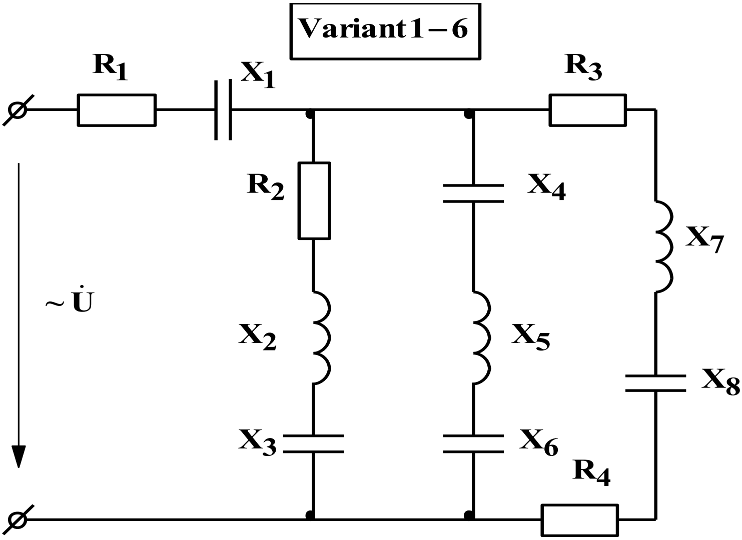
The resonance frequency

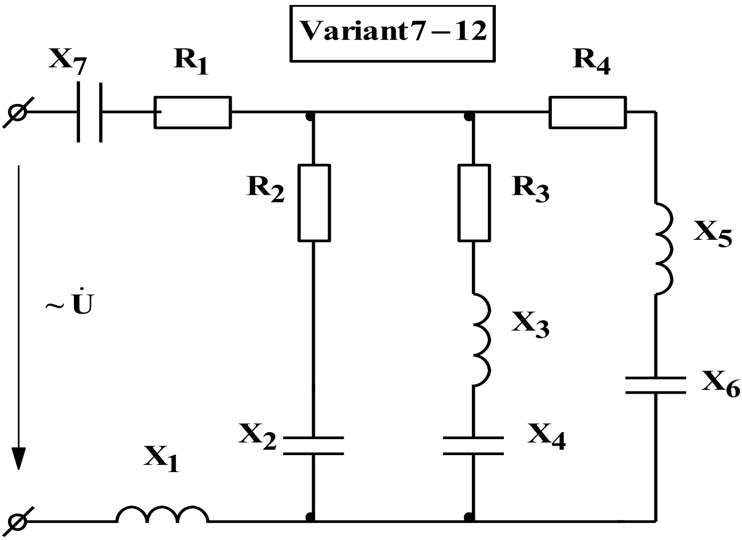
$$f_r = \frac{\omega}{2\pi} = \frac{69.4}{2\pi} = 11.05\ Hz$$

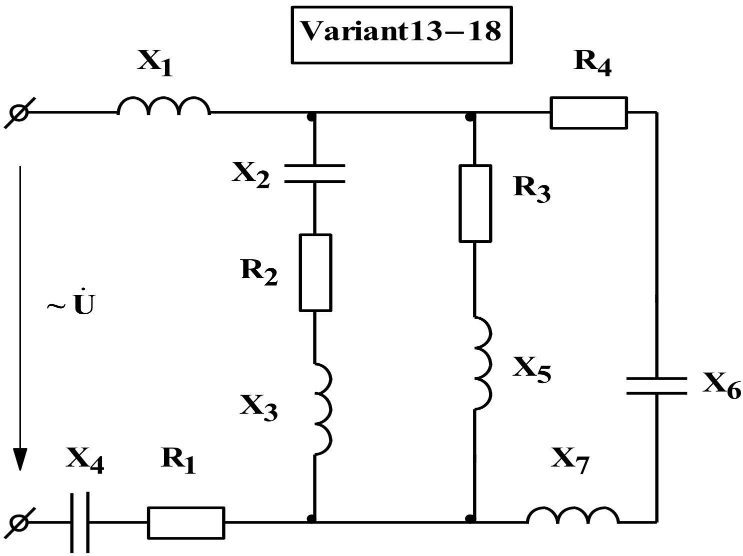
Appendix B Data for calculation

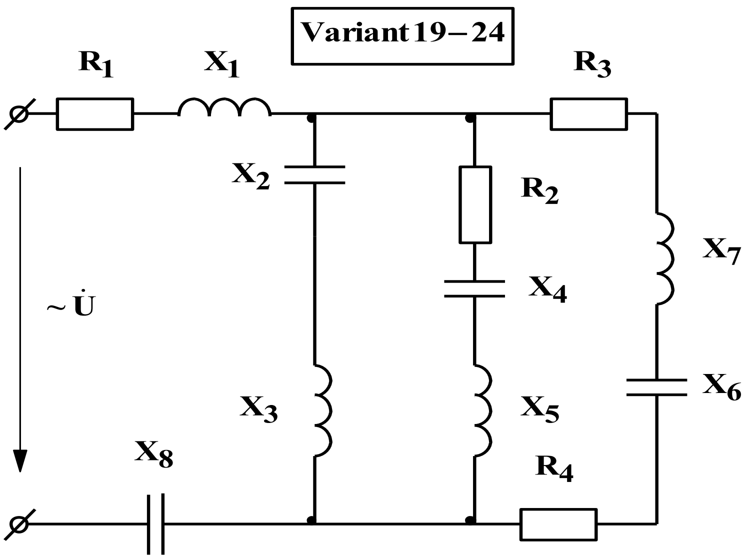
V	U	R_1	R_2	R_3	R_4	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
1	100	30	0	20	50	10	30	0	0	0	40	60	20
2	60	25	0	0	40	0	40	60	0	80	60	0	30
3	80	0	20	10	0	20	30	0	0	40	0	25	45
4	140	0	0	60	30	50	20	35	20	0	40	0	50
5	120	30	0	20	0	30	40	0	25	15	0	20	30
6	100	0	20	0	30	0	40	20	50	60	0	30	70
7	60	20	20	0	35	50	20	70	0	35	0	20	-
8	80	10	30	0	50	40	0	50	25	0	50	30	-
9	100	40	0	20	25	80	0	40	20	25	0	40	-
10	70	60	30	0	0	60	30	80	0	60	40	0	-
11	50	50	0	30	0	0	70	70	40	80	30	0	-
12	120	0	0	40	30	45	35	80	30	60	20	0	-
13	160	0	50	60	70	65	0	40	35	40	70	0	-
14	100	45	0	20	20	0	80	50	0	35	60	80	-
15	80	0	40	80	0	40	0	40	20	80	90	50	-
16	60	20	40	0	25	20	30	70	0	60	75	50	-
17	120	0	40	0	40	0	40	80	50	70	75	45	-
18	50	0	0	60	80	45	70	60	0	40	0	80	-
19	80	0	80	70	0	0	30	40	50	70	80	0	60
20	100	20	60	0	0	20	40	50	60	0	30	40	0
21	120	0	35	0	45	70	60	50	40	30	0	50	0
22	60	40	0	45	60	40	0	60	70	80	0	60	0
23	120	40	0	30	0	50	40	0	35	15	0	40	30

Appendix C The diagrams of electric circuits for calculation






Variant13−18
X1
R4
X2
R3
R2
~ U̇
X5
X6
X3
X4
R1
X7


Variant19−24
R1
X1
R3
X2
R2
X7
~ U̇
X4
X6
X3
X5
X8
R4

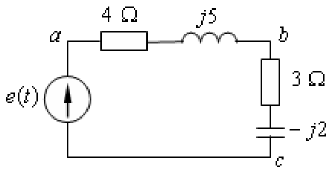
The tasks for protection of this topic

1 A voltage of $e(t) = 150\sin 1000t$ is applied across a series *RLC* circuit where $R = 40\,\Omega,\ L = 0.13\ H, and\ C = 10\ \mu F$. (a) Compute the current and voltages appearing across the capacitor and inductor terminals. (b) Draw the complete phasor diagram for the solution of this problem showing all voltage components.

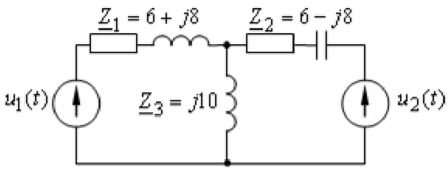
2. In the following circuit the applied forcing function is given by $e(t) = 141\sin\omega t$.

(a) Express the voltage drops across terminals *ab* and *bc* in terms of phasor notation.

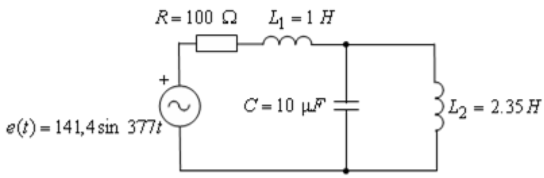
(b) Draw a phasor diagram showing $\underline{U}_{ab} + \underline{U}_{bc}$ and using current as the reference phasor.



3. Find the current which flows through the branch with Z_3 if $\underline{U}_1 = 100\ V,\ \underline{U}_2 = 100e^{-j60^o}\ V$. Use the nodal method.



4. Refer to the next circuit.



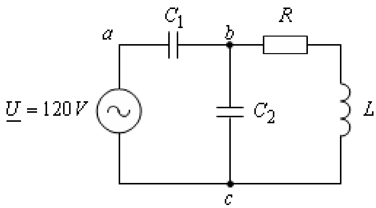
(a) Find the equivalent reactance for the parallel branches.

(b) Determine currents in branches.

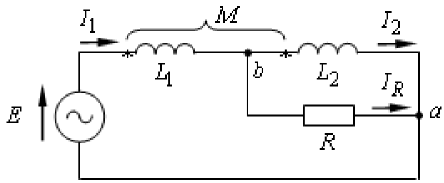
5. A series *RLC* circuit has the following parameter values: $R = 10\ \Omega$, $L = 0.01\ H$, $C = 100\ \mu F$. Compute the resonant frequency in radians per second. Calculate the quality factor of the circuit.

6. In the following circuit the reactance of capacitor C_1 is 4 Ω, the reactance of C_2 is 8 Ω, the reactance of *L* is 8 Ω and active resistance *R* is 4Ω. The effective voltage of 120 *V* is applied to the circuit.

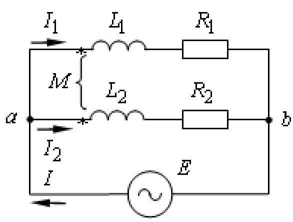
(a) Find the effective value of the current delivered by the source. (b) Write the expression for the instantaneous value of the current found in part (a). (c) Draw a carefully labeled phasor diagram showing the source voltage, the source current, and voltages $\underline{U}_{ab}$ and $\underline{U}_{bc}$.



7. Find the currents in the circuit and plot a combine vector diagram of currents and voltages. The circuit parameters: $E = 100\,V$; $\omega L_1 = 2\ \Omega$; $\omega L_2 = 3\ \Omega$; $\omega M = 1\ \Omega$; $R = 4\Omega$.



9. Calculate the currents in parallel branches and plot a vector diagram of currents and voltages. The circuit parameters: $E = 100\,V$; $\omega L_1 = 3\ \Omega$; $\omega L_2 = 4\ \Omega$; $\omega M = 3\ \Omega$; $R_1 = R_2 = 4\Omega$.



RECOMMENDED LITERATURE

1. The schoolbook "Theoretical Electrical Engineering" / Nabokova O.V. - Zaporozhye: ZNTU, 2014. - 530 p.
2. Козлов В.В., Набокова О.В. Теоретичні основи електротехніки. Усталені режими у лінійних електричних колах. -Запоріжжя: ЗНТУ, 2016. – 428 с.
3. Мілих В.І. Електротехніка та електромеханіка. К.: Каравелла, 2010. – 376 с.
4. Паначевський Б.І., Свергун Ю.Ф. Загальна електротехніка: Теорія і практикум. К.: Каравелла, 2005. – 440 с.
5. Paul C.R., Nazzsar S.A. Introduction to electrical engineering. - New York: Electrical Engineering University of Kentucky, 1999. - 800 p.