

*Міністерство освіти і науки України
Тернопільський національний технічний університет
імені Івана Пулюя*

*кафедра
світлотехніки та
електротехніки*


література

навчально-методична

Electrical Engineering
LABORATORY WORKS

Ternopil 2017

«Electrical Engineering. Laboratory works.»

Укладач: Н.А. Куземко. Тернопіль: ТНТУ, 2014. –

Укладач: к.т.н., доц. Куземко Н.А.

Рецензент: д.т.н., проф. Лупенко А.М.

Редагування англійською мовою: к.п.н., доц. Кухарська В.Б.

Комп'ютерний набір: Куземко Н.А.

Затверджено на засіданні кафедри світлотехніки та електротехніки Тернопільського національного технічного університету імені Івана Пулюя.

Протокол № 6 від 28 лютого 2014 року

Схвалено й рекомендовано до друку методичною радою **електромеханічного** факультету Тернопільського національного технічного університету імені Івана Пулюя.

Протокол № 6 від 20 березня 2014 року

Посібник складено відповідно до робочих програм курсів “Електротехніка, електроніка та основи МПТ”, “Електротехніка в будівництві”, “Теорія електричних та магнітних кіл”.

LABORATORY WORK 1

Investigation

of energy transfer from source to consumer

The purpose of the work. To investigate the energy transfer from source to consumer, electrical source working regimes and to learn practically how to determine the source parameters.

Homework

At given voltage V , load resistance R , and efficiency factor η of the circuit on fig.1.8 to define source internal resistance R_0 and electromotive force E , source and consumer powers P_E, P_R . To calculate the efficiency factor when the load will be $R/10$. Tasks variants are listed in the table 1.1.

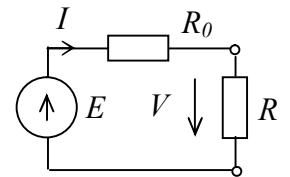


Fig. 1.8

Table 1.1

| Var | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------|------|------|------|------|------|------|------|------|------|------|
| η | 0.91 | 0.92 | 0.93 | 0.94 | 0.95 | 0.96 | 0.97 | 0.98 | 0.99 | 1.00 |
| R, Ω | 51 | 62 | 73 | 84 | 95 | 106 | 117 | 128 | 139 | 150 |
| V, V | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 100 |

Elements of laboratory settings

Laboratory settings consist of the power supply БП4822-2, clamps terminal, board 5, measuring devices.

The elements of the board 5: variable resistors $R_{гр}$ «Грубо», $R_{т}$ «Точно», R_c – switch of the resistors $R_2 \div R_{10}$.

Measuring devices: $PV(P\Omega)$ – multimeter Ш4300 to measure voltage, options: $\langle - \rangle$, $\langle V \rangle$, $\langle 200 V \rangle$; to measure resistance, options: $\langle - \rangle$, $\langle R \rangle$, $\langle 2 \kappa\Omega \rangle$; PmA – milliamperemeter Э536, limit of measuring $\langle 100 mA \rangle$. The way of measuring devices placement is shown in fig. 1.9.

The work execution order

1. Connect the multimeter $P\Omega$ to clamps 3-4 and by using the switch R_c measure the resistances $R_2 \div R_{10}$. Write down the results to the table 1.2.

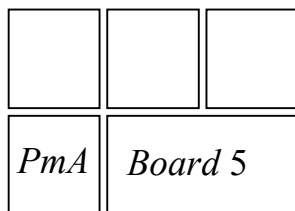


Fig. 1.9

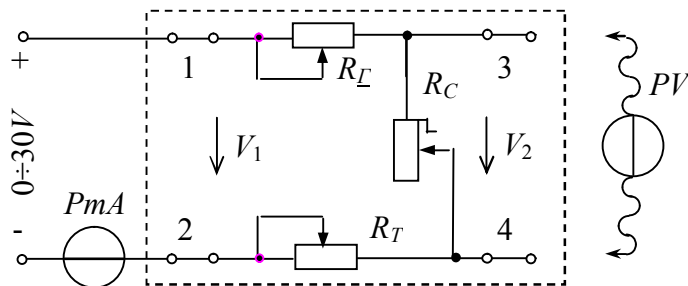


Fig. 1.10

2. Connect the multimeter $P\Omega$ to clamps 1-2, short clamps 3-4 and set the line resistance $R_L = R_6$ by variable resistors $R_{гр}$ «Грубо», $R_{т}$ «Точно».

3. Collect the circuit (fig. 1.10) and connect it to the clamps $\langle - \rangle$ $\langle 0 \div 30 V \rangle$. Place *LATR* switch in position $\langle - \rangle$, $\langle 0 \div 30 V \rangle$.

4. Short the clamps 3–4 and set the short circuit current $I_{sc} = 100 mA$. Write down the results of measuring to the table 1.2 item sc. Open the clamps 3–4 and measure the open circuit voltage. Write down the results of measuring to the table 1.2 item oc.

5. Set the voltage across clamps 1–2 $V_1 = V_{loc}$ and maintaining it constant during the experiment ($V_1 = const$), change the resistance R_c turning it from 2 to 10 positions. Write down the results of measuring to the table 1.2, items 2-10.

6. Calculate (table 1.2): the consumer resistances $R_c = V_2 / I$, the voltage drops $\Delta V = V_1 - V_2$, the input power $P_1 = V_1 I$, the output power $P_2 = V_2 I$, the power losses $\Delta P = P_1 - P_2$, the efficiency factor $\eta = P_2 / P_1$. Write down the results of calculations to the table 1.2.

7. Define electromotive force $E = V_{loc}$, the source internal resistance $R_0 = (V_{loc} - V_{1sc}) / I_{sc}$ and the line resistance $R_L = V_{1sc} / I_{sc}$.

8. Determine the current source parameters J , G_0 for known voltage source parameters E , R_0 . Draw the current source and the voltage source substitutional schemes.

Table 1.2.

| <i>Measurements</i> | | | | | <i>Calculations</i> | | | | | |
|---------------------|-------------------|--------------|-------------|--------------|---------------------|-------------------|--------------|--------------|-------------------|--------|
| <i>Nº</i> | R_c Ω | V_1 V | I mA | V_2 V | R_c Ω | ΔV V | P_1 W | P_2 W | ΔP W | η |
| sc | | | | | | | | | | |
| oc | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |

9. Draw graphs: $V_1(I)$, $V_2(I)$, $\Delta V(I)$ and $P_1(I)$, $P_2(I)$, $\Delta P(I)$, $\eta(I)$ by using the table 1.2

Make conclusions about electrical source working regimes, the methods of determining the source parameters, the value of losses, the efficiency factor and how the source output voltage change when the load increase.

Report on the work

The name and the purpose of the work. Homework – the calculation of the circuit. The schematic diagram of the investigated circuit (fig 1.10). The table 1.2.

The results of calculations of source parameters. The graphs. The conclusions.

Control questions

1. Give the definition of electrical circuit. Draw the simplest electrical circuit and mark the directions of electrical values in it. What are the main and the additional elements of the electrical circuit, what are their purposes?
2. Name and characterize the main circuit working regimes.
3. What devices do we call consumers? What parameter characterizes the measure of energy transfer?
4. Draw the consumer conditional designation and mark the directions of the electrical values in it. Write down the Ohm's law and the power expression for the consumer.
5. What devices do we call the power sources? What parameter characterizes the ideal source?
6. Draw the power source conditional designation and mark the directions of electrical values in it. Write down the power expression for it.
7. How to choose the circuit current direction? What is the condition of generator working regime and consumer working regime of the electrical source?
8. What are the main parameters of the voltage source? What is the difference between real and ideal voltage source?
9. Draw the serial substitution scheme of electrical source. Write down the voltage source equation.
10. Draw the parallel substitution scheme of electrical source. Write down the current source equation.
11. How can we determine the voltage source parameters experimentally? Write down the relevant expressions.
12. Draw the external characteristics of real and ideal voltage source and current source.
13. Describe the work of electrical source in the voltage generator regime. What is the working regime condition?
14. Describe the work of electrical source in the current generator regime. What is the working regime condition?
15. Describe the agreed working regime of the electrical source. What is the working regime condition?
16. Write down the electrical source efficiency factor expression using the parameters of the source and consumer. Analyze the dependence between the source working regime and the efficiency factor.

LABORATORY WORK 2

Investigation

of mixed connection of resistive elements

Homework

To calculate the current in a circle

5

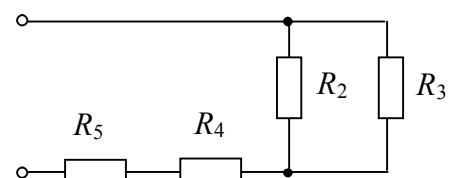


Fig.2.16

(fig. 2.16), if known the resistances of resistors R_2, R_3, R_4, R_5 and the maximum power P_n allocated to the resistor R_n in the unforked circuit. To define total current, input voltage and subcircuits voltages, branches currents, power of the circuit and the powers of subcircuits. To write down the results to the table 2.2 item 1. Tasks variants are listed in the table 2.1.

Table 2.1

| | | | | | | | | | | |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| <i>Var №</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| P_n, W | 7.1 | 7.2 | 7.3 | 7.4 | 7.5 | 7.1 | 7.2 | 7.3 | 7.4 | 7.5 |
| R_2, Ω | 150 | 155 | 160 | 165 | 170 | 165 | 155 | 160 | 165 | 170 |
| R_3, Ω | 204 | 186 | 232 | 197 | 203 | 205 | 195 | 181 | 203 | 228 |
| R_4, Ω | 198 | 193 | 228 | 198 | 196 | 197 | 199 | 208 | 191 | 231 |
| R_5, Ω | 198 | 212 | 235 | 193 | 201 | 202 | 164 | 211 | 192 | 229 |

Elements of laboratory settings

Laboratory settings consist of the power supply *БП4822-2*, clamps terminal, board 1, measuring devices.

The elements of the board 1: resistors R_1, R_2, R_3, R_4 .

Measuring devices: $PV(P\Omega)$ – multimeter *Ц4300* to measure voltage, options: $\langle - \rangle, \langle V \rangle, \langle 200 V \rangle$; to measure resistance, options: $\langle - \rangle, \langle R \rangle, \langle 2 \kappa\Omega \rangle$; PA – ammeters *Э536*, limit of measuring $\langle 0.5 A \rangle$; PW – wattmeter for measuring power, limit of measuring: $\langle 75 V / 0.5 A \rangle$. The way of measuring devices placement is shown in fig. 2.17.

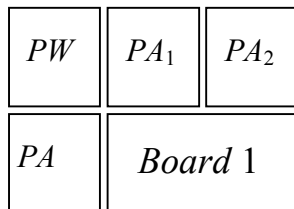


Fig. 2.17

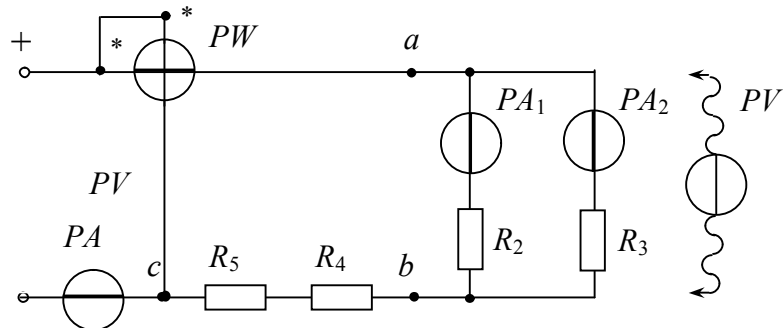


Fig. 2.18

The work execution order

1. To collect the circuit (fig. 2.18) and connect it to the clamps $\langle - \rangle \langle 0 \div 120 V \rangle$. To place *LATR* switch in position $\langle - \rangle, \langle 0 \div 120 V \rangle$.

2. To investigate the circuit with mixed connection of resistors (fig. 2.18). To set the input voltage given by tutor ($80 \leq V \leq 100 V$). To write down the results to the table 2.2 item 2.

Table 2.2

| <i>№</i> | <i>Measurements</i> | | | | | | | | | <i>Calculation</i> | |
|----------|---------------------|-------------|-------------|----------|----------|--------|----------|----------|--------|--------------------|-------------|
| | V, V | V_{23}, V | V_{45}, V | V_4, V | V_5, V | I, A | I_2, A | I_3, A | P, W | P_{23}, W | P_{45}, W |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |

To verify the results for the balance of power: $P = P_{23} + P_{45}$.

3. To investigate the circuit with parallel connection of resistors R_2, R_3 . To short the series subcircuit R_4, R_5 (points b, c fig. 2.18). To set the input voltage given by tutor ($14 \leq V \leq 18 V$). To write down the results to the table 2.3.

Table 2.3

| Measurements | | | | | | Calculations | | |
|--------------|------------------|-------------|---------------|---------------|-------------|--------------------|--------------------|-----------------------|
| $N\circ$ | $V_{23},$ V | $I,$ A | $I_2,$ A | $I_3,$ A | $P,$ W | $R_2,$ Ω | $R_3,$ Ω | $R_{23},$ Ω |
| 1 | | | | | | | | |

To verify the results for the first Kirchoff's law: $I = I_2 + I_3$. To calculate the resistances of resistors R_2, R_3 and the equivalent resistance of a parallel connection R_{23} .

4. To investigate the circuit serial connection of resistors R_4, R_5 . To shorten the parallel subcircuit R_2, R_3 (points a, b fig. 2.18). To set the circuit current given by tutor ($170 \leq I \leq 200 mA$). To write down the results to the table 2.4.

Table 2.4

| Measurements | | | | | | Calculations | | |
|--------------|-------------|------------------|---------------|---------------|-------------|--------------------|--------------------|-----------------------|
| $N\circ$ | I mA | $V_{45},$ V | $V_4,$ V | $V_5,$ V | $P,$ W | $R_4,$ Ω | $R_5,$ Ω | $R_{45},$ Ω |
| 1 | | | | | | | | |

To verify the results for the second Kirchoff's law: $V_{45} = V_4 + V_5$. To calculate the resistances of resistors R_4, R_5 and the equivalent resistance of a series R_{45} .

5. To draw the circuit of current divider R_2, R_3 . To define analytically currents I_2, I_3 at given current I (table 2.3.).

6. To draw the circuit of voltage divider R_4, R_5 . To define analytically voltages V_4, V_5 at given voltage U_{45} (table 2.4.).

Report on work

The name and purpose of the work. Homework – the calculation of the circuit. Schematic diagram of the investigated circuit (fig 2.18). Tables 2.2, 2.3, 2.4. The schemes of circuits of current divider and voltage divider. The results of calculations. Conclusions.

Control questions

1. Which device is called a one-port network? To provide the examples of one-port networks. What one-port networks are called active, and what – passive?
2. Give the definition of branch, node and loop of the electrical circuit.
3. What types of the electrical connections in the circle are called simple? What is main difference the complex connection?
4. Write down the circuit electrical status equation consisting of three serially connected resistors and expression of equivalent resistance of this circuit.

5. Write down the circuit electrical status equation consisting of three parallel connected resistors and expression of equivalent conductivity of this circuit.
6. Write down the equivalent resistance of the circuit with mixed connected resistors (parallel-serial and serial-parallel).
7. What types of connections in the circuit are called complex?
8. Write down the expressions of the equivalent transformation of “delta” in „wye”.
9. What is the essence of the method of simplification of electrical circuit?
10. To draw the circuit of voltage divider. Write down proper expressions for it.
11. To draw the circuit of current divider. Write down proper expressions for it.

LABORATORY WORK 3

Investigation

of resistor, inductance and capacitor in AC circuit

The purpose of the work is to define the parameters of resistor, inductance and capacitors in AC circuit.

Homework

To calculate the impedance, input voltage, phase shift angle, active and reactive powers, coil quality factor in a circuit (fig. 3.9), at given current I , inductivity L , active resistance R . To write down the results to the table 3.3 line 1. Tasks variants are listed in the table 3.1.

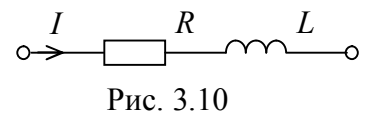


Рис. 3.10

Table 3.1.

| <i>Var. №</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---------------|------|------|------|------|------|------|------|------|------|------|
| <i>I, A</i> | 0.21 | 0.22 | 0.23 | 0.24 | 0.25 | 0.21 | 0.22 | 0.23 | 0.24 | 0.25 |
| <i>L, H</i> | 0.79 | 1.08 | 1.01 | 1.10 | 1.09 | 1.12 | 1.13 | 1.15 | 1.18 | 1.20 |
| <i>R, Ω</i> | 163 | 181 | 175 | 185 | 182 | 186 | 189 | 187 | 197 | 195 |

Elements of laboratory settings

Laboratory settings consist of the power supply БП4822–2, clamps terminal, board 2, measuring devices.

The elements of the board 2 are capacitors C_1, C_2, C_3 , resistor R , coil L .

Measuring devices are: $PV(P\Omega)$ – multimeter Ш4300 to measure voltage, options: $\langle \sim \rangle, \langle V \rangle, \langle 200 V \rangle$; to measure resistance, options: $\langle - \rangle, \langle R \rangle$,

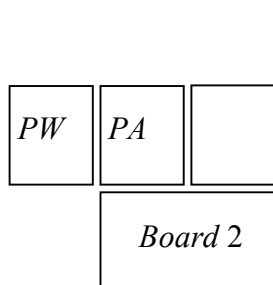


Fig. 3.10

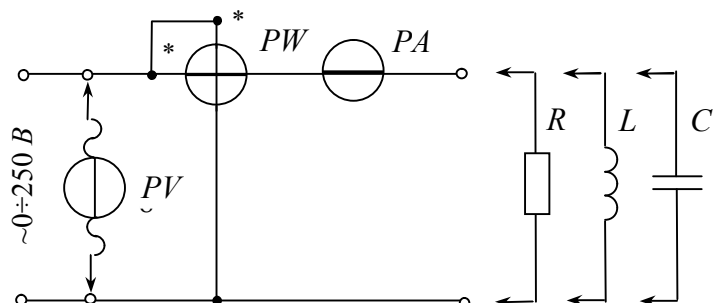


Fig. 3.11.

$<2 \kappa\Omega>$; PA – amperemeter Э536, limit of measuring $<0.5 A>$; PW – wattmeter for measuring power, limit of measuring: $<150 V / 0.5 A>$. The way of measuring devices placement is shown in fig. 3.11.

The work execution order

1. To collect the circuit (fig. 3.11) and connect it to the clamps $<\sim>$ $<0 \div 250 V>$. To place $LATR$ switch in position $<\sim>$, $0 \div 250 V$.
2. To investigate the circuit with resistor R . To set the input voltage as given by tutor ($100 \leq V \leq 120 V$). To write down the results to the table 3.2.

Table 3.2

| Measurements | | | | Calculations | | | | |
|--------------|------------------|-------------|-------------|--------------|------------------|--------------|---------------|---------------------|
| | $R,$ Ω | $V,$ V | $I,$ A | $P,$ W | $R,$ Ω | G mSm | $\cos\varphi$ | $\varphi,$ deg |
| | | | | | | | | |

Calculate (table 3.2): active resistance $R = V / I$, conductivity $G = I / V$, phase shift angle φ , power factor $\cos\varphi = P / VI$. Draw the vector diagram.

3. Investigate the circuit with coil L without core. Set the input voltage as given by tutor ($70 \leq U \leq 80 V$). Write down the results to the table 3.3, line 2.

Table 3.3

| Measurements | | | | Calculations | | | | | | |
|----------------|-------------|-------------|-------------|------------------|------------------|------------------|---------------------|---------------|-------------|-----|
| $N\varnothing$ | $I,$ A | $V,$ V | $P,$ W | $Z,$ Ω | $R,$ Ω | $X,$ Ω | $\varphi,$ deg | $Q,$ VAr | $L,$ H | d |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |

Calculate and put in table 3.3: coil impedance $Z = V / I$, active resistance R ($P = RI^2$) and reactance X ($Z = \sqrt{R^2 + X^2}$), phase shift angle φ ($tg\varphi = X / R$), reactive power $Q = XI^2$, inductance L ($X = \omega L$) and coil quality factor $d = Q / P$. Draw the vector diagram.

4. Investigate the circuit with capacitances: C_1 , C_{12} serial, C_{12} parallel. Set the input voltage as given by tutor ($60 \leq U \leq 90 V$). Write down the results to the table 3.4.

Table 3.4

| Measurements | | | | Calculations | | | | | | |
|----------------|-------------|-------------|-------------|---------------|---------------|---------------|-----------------|---------------|------------|---------------------|
| $N\varnothing$ | $V,$ V | $I,$ A | $P,$ W | $Y,$ mSm | $G,$ mSm | $B,$ mSm | $C,$ μF | $Q,$ VAr | $tg\delta$ | $\varphi,$ deg |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |

Calculate and put in table 3.4: admittance Y ($I = YV$), active G ($P = GV^2$) and reactive B ($Y = \sqrt{G^2 + B^2}$) conductivities, capacity C ($B = \omega C$), reactive power $Q = BV^2$, dissipation factor $tg\delta = P / Q$, phase shift angle φ ($\varphi = 90 - \delta$).

Draw the vector diagram.

5. Draw the coil parallel substitution scheme. Calculate the conductance G' and inductance L' of parallel substitution scheme according to the parameters of serial substitution scheme R, X (table 3.3, item 2), using formulas $G' = R/Z^2$, $B' = X/Z^2$, $L' = B'/\omega$.

6. Draw the capacitor serial substitution scheme. Calculate the resistance R' and capacitance C' of serial substitution scheme according to the parameters of parallel substitution scheme G, B (table 3.4, line 2), using formulas $R' = G/Y^2$, $X' = B/Y^2$, $C' = B/\omega$.

Report on work

The name and purpose of the work. Homework – the calculation of the circuit. Schematic diagram of the investigated circuit (fig 3.11). Tables 3.2, 3.3, 3.4. The substitutional schemes of coil and capacitor and calculations of their parameters. Vector diagrams for resistance, coil and capacitor. Conclusions.

Control questions

1. Give a definition of alternating current. What's the period of alternating current?
2. What are the parameters of alternating current?
3. Explain what is it instantaneous value of alternating current and phase shift angle.
4. Explain what is it the effective value of alternating current and its connection with the amplitude value.
5. Write down the amplitude-phase relationship for R -element.
6. Write down the amplitude-phase relationship for L -element.
7. Write down the amplitude-phase relationship for C -element.
8. Draw vector diagrams for resistive, inductive and capacitive element.
9. Write down the expressions of reactance, conductivity and power for inductive element.
10. Write down the expressions of reactance, conductivity and power for capacitive element.
11. Explain the physical essence of the coil substitutional schemes elements and draw these schemes.
12. Explain the physical essence of the capacitor substitutional schemes elements and draw these schemes.
13. Write down the expressions for the coil quality factor and capacitor dissipation factor.

LABORATORY WORK 4

Investigation

of coil and capacitor serial connection

Homework

Calculatate the input voltage, coil voltage,

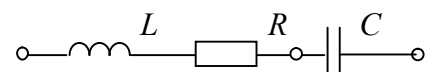


Fig. 4.9

capacitor voltage active and reactive powers, the resistances of the elements and phase shift angles (fig. 4.9), at given current I , inductivity L , active resistance R , capacitance C . Write down the results to the table 4.2 line 1. Tasks variants are listed in the table 4.1.

Table. 4.1

| | | | | | | | | | | |
|-------------|------|------|------|------|------|------|------|------|------|------|
| Var | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| I, mA | 180 | 185 | 190 | 195 | 200 | 180 | 185 | 190 | 195 | 200 |
| R, Ω | 186 | 189 | 187 | 197 | 195 | 186 | 189 | 187 | 197 | 195 |
| L, H | 1.12 | 1.13 | 1.15 | 1.18 | 1.20 | 1.12 | 1.13 | 1.15 | 1.18 | 1.20 |
| $C, \mu F$ | 3.92 | 3.76 | 3.78 | 3.86 | 3.87 | 6.15 | 6.33 | 6.02 | 6.51 | 6.34 |

Elements of laboratory settings

Laboratory settings consist of the power supply $BII4822-2$, clamps terminal, board 2, measuring devices.

The elements of the board 2 are capacitors C_1, C_2, C_3 , coil L .

Measuring devices are: $PV(P\Omega)$ – multimeter $III4300$ to measure voltage,

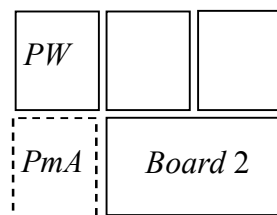


Fig. 4.10

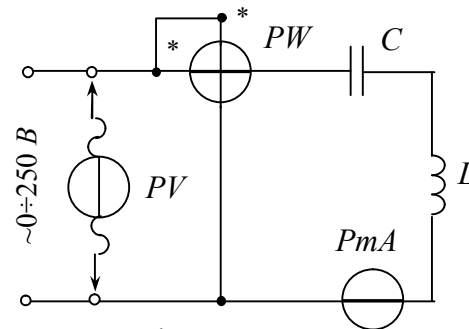


Fig. 4.11

options: $\langle \sim \rangle$, $\langle V \rangle$, $\langle 200 V \rangle$; PA – amperemeter $\mathcal{E}536$, limit of measuring $\langle 0.5 A \rangle$; PW – wattmeter for measuring power, limit of measuring: $\langle 150 V / 0.5 A \rangle$. The way of measuring devices placement is shown in fig. 4.10.

The work execution order

1. Collect the circuit (fig. 4.11) and connect it to the clamps $\langle \sim \rangle$ $\langle 0 \div 250 V \rangle$. Place $LATR$ switch in position $\langle \sim \rangle$, $0 \div 250 V$.
2. Investigate the circuit with the serial connection of coil without core and capacitor C_2 . Set the circuit current as given by tutor ($180 \leq I \leq 200 mA$). Write down the results to the table 4.2, line 2.
3. Investigate the circuit with the serial connection of coil without core and capacitors C_{23} (parallel connection of C_2 and C_3). Set the circuit current as given by tutor ($180 \leq I \leq 200 mA$). Write down the results to the table 4.2, line 3.

Table 4.2

| $N\acute{o}$ | Measurements | | | | | Calculations | | | | | | | |
|--------------|--------------|--------|----------|----------|--------|--------------|-------------|---------------|---------------|------------------|---------------|-------------|----------------|
| | I, mA | V, V | V_C, V | V_L, V | P, W | Z, Ω | R, Ω | Z_L, Ω | X_L, Ω | φ_L, deg | X_C, Ω | X, Ω | φ, deg |
| | | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|--|--|--|--|--|--|--|--|--|--|--|--|--|
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | |

Calculate and put in table 4.2: circuit impedance $Z = V/I$, coil impedance $Z_L = V_L/I$, active resistance $R (P = RI^2)$ and coil reactance $X_L (Z_L = \sqrt{R^2 + X_L^2})$, coil phase shift angle $\varphi_L (tg\varphi_L = (X_L / R))$, capacitor reactance $X_C = V_C/I$, circuit reactance $X = X_L - X_C$, circuit phase shift angle φ .

4. Investigate the circuit with serial connection of coil and capacitor C_1 . Set the input voltage as given by tutor ($50 \leq V \leq 70 V$):

– coil without a core (minimal inductivity) and write down the results to the table 4.3, line 1;

– coil with a core (maximum inductivity) and write down the results to the table 4.3, line 2;

– in resonance regime (moving the core in the coil till the current will be maximum (the indication of resonance) and write down the results to the table 4.3, line 3.

Table 4.3

| Measurements | | | | | | Calculations | | | | | | | |
|----------------|--------|---------|----------|----------|--------|--------------|-------------|---------------|---------------|------------------|---------------|-------------|----------------|
| $N\varnothing$ | V, V | I, mA | V_C, V | V_L, V | P, W | Z, Ω | R, Ω | Z_L, Ω | X_L, Ω | φ_L, deg | X_C, Ω | X, Ω | φ, deg |
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | |

Calculate and put in table 4.3: circuit impedance $Z = V/I$, coil impedance $Z_L = V_L/I$, active resistance $R (P = RI^2)$ and coil reactance $X_L (Z_L = \sqrt{R^2 + X_L^2})$, coil phase shift angle $\varphi_L (tg\varphi_L = (X_L / R))$, capacitor reactance $X_C = V_C/I$, circuit reactance $X = X_L - X_C$, circuit phase shift angle $\varphi (tg\varphi = (X / R))$. Draw three vector diagrams using the data from table 4.3. Losses in capacitors are negligible, that's why the capacitor phase shift angle will be $\varphi_C = -\pi / 2$.

Report on work

The name and purpose of the work. Homework – the calculation of the circuit. Schematic diagram of the investigated circuit (fig 4.11). Tables 4.2, 4.3. The substitutional schemes of coil and capacitor and calculations of their parameters. The vector diagrams. Conclusions.

Control questions

1. Write down the electrical status equation for the circuit with serial connection of RLC -elements in vector form and draw the vector diagram for this circuit.

2. Draw resistances calculated triangle for the circuit with serial connection of RLC -elements and write down the corresponding relations for it.

3. Explain what is it the active and reactive voltage constituents.
4. Draw powers calculated triangle for the circuit with serial connection of *RLC*-elements and write down the corresponding relations for it.
5. Give the definition of voltage resonance, write down the resonance condition and explain the resonance indication.
6. Give the definition of voltage resonance frequency, circuit wave resistance and explain the ways of resonance reaching.
7. What is the impedance, phase shift factor and total power of the voltage resonance circuit? How voltage resonance is being applied?
8. Draw the voltage resonance circuit frequency characteristics.
9. Draw the resonance curve for the voltage resonance circuit. Explain why the current at resonance is the biggest.

LABORATORY WORK 5

Investigation

of coil and capacitor parallel connection

The purpose of the work is to investigate parallel connection of coil and capacitor and the current resonance in AC circuit.

Homework

Calculatate the current in the unforked subcircuit, coil current I_L , capacitor current I_C , active and reactive powers, the conductivities of the elements and phase shift angles in the circuit (fig. 5.9), at given voltage V , inductivity L , active resistance R , capacitances C . Write down the results to the table 5.2 line 1. Tasks variants are listed in the table 5.1.

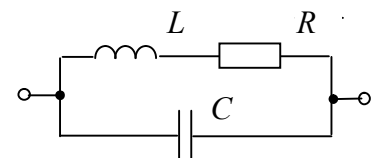


Fig.5.9

Table 5.1

| <i>Var</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------|------|------|------|------|------|------|------|------|------|------|
| V, V | 50 | 55 | 60 | 65 | 70 | 50 | 55 | 60 | 65 | 70 |
| R, Ω | 186 | 189 | 187 | 197 | 195 | 186 | 189 | 187 | 197 | 195 |
| L, H | 1.12 | 1.13 | 1.15 | 1.18 | 1.20 | 1.12 | 1.13 | 1.15 | 1.18 | 1.20 |
| $C, \mu F$ | 3.99 | 3.77 | 3.83 | 3.82 | 3.79 | 4.17 | 4.15 | 4.12 | 4.17 | 4.11 |

Elements of laboratory settings

Laboratory settings consist of the power supply *БП4822-2*, clamps terminal, board 2, measuring devices.

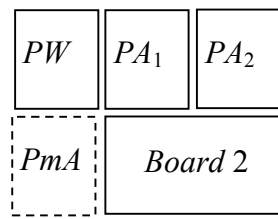


Fig. 5.10

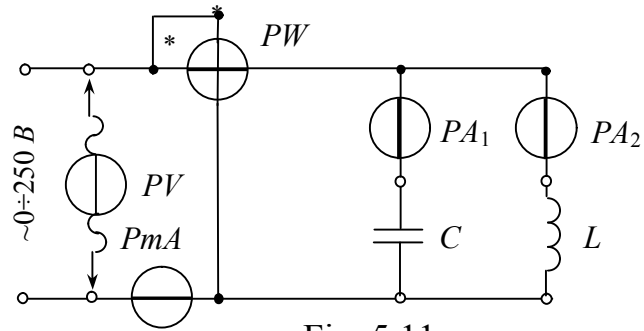


Fig. 5.11

The elements of the board 2 are capacitors C_1, C_2, C_3 , coil L .

Measuring devices are: PV – multimeter $III4300$ to measure voltage, options: $\langle \sim \rangle, \langle V \rangle, \langle 200 V \rangle$; PA – ammeters $\text{Э}536$, limit of measuring $\langle 0.5 A \rangle$; PmA – milliamperemeter, limit of measuring $\langle 200 mA \rangle$, PW – wattmeter for measuring power, limit of measuring: $\langle 150 V / 0.5 A \rangle$. The way of measuring devices placement is shown in fig. 5.10.

The work execution order

1. To collect the circuit (fig. 5.11) and connect it to the clamps $\langle \sim \rangle \langle 0 \div 250 V \rangle$. To place $LATR$ switch in the position $\langle \sim \rangle, 0 \div 250 V$.
2. To investigate the circuit with parallel connection of coil without a core and capacitor C_1 . To set the input voltage as given by tutor ($50 \leq U \leq 70 V$). To write down the results to the table 5.2, line 2.
3. To investigate the circuit with parallel connection of coil without a core and capacitors C_{13} (parallel connection of C_1 and C_3). To set the input voltage as given by tutor ($50 \leq U \leq 70 V$). To write down the results to the table 5.2, line 3.

Table 5.2

| Measurements | | | | | | Calculations | | | | | | |
|--------------|--------|---------|----------|----------|--------|--------------|------------|------------|------------------|------------|----------|----------------|
| $N\bar{o}$ | V, V | I, mA | I_C, A | I_L, A | P, W | G, mSm | B_L, mSm | Y_L, mSm | φ_L, deg | B_C, mSm | B, mSm | φ, deg |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |

calculate and put in table 5.2: coil admittance $Y_L = I_L / V$, coil active $G = R \cdot Y_L^2$ ($R = P / I_L^2$) and reactive B_L ($Y_L = \sqrt{G_L^2 + B_L^2}$) conductivities, coil phase shift angle φ_L ($tg \varphi_L = (-B_L / G)$); capacitor reactive conductivity $B_C = I_C / V$, circuit reactive conductivity $B = B_L - B_C$, circuit phase shift angle φ ($tg \varphi = (B / G)$).

4. To investigate the circuit with parallel connection of coil and capacitor C_2 . To set the input voltage as given by tutor ($90 \leq V \leq 110 V$):

- coil without a core (minimal inductivity) and write down the results to the table 5.3, line 1;
- coil with a core (maximum inductivity) and write down the results to the

table 5.3, line 2;

– in resonance regime (by moving the core in the coil till the current will be minimum – what is an indication of resonance) and write down the results to the table 5.3, line 3.

Table 5.3

| <i>Measurements</i> | | | | | | <i>Calculations</i> | | | | | | |
|---------------------|-------------|--------------|---------------|---------------|-------------|---------------------|-----------------|-----------------|-----------------|---------------|-----------------------|---------------------|
| N_2 | $V,$ V | $I,$ mA | $I_L,$ A | $I_C,$ A | $P,$ W | $G,$ mSm | $B_L,$ mSm | $Y_L,$ mSm | $B_C,$ mSm | $B,$ mSm | $\varphi_L,$ deg | $\varphi,$ deg |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |

Calculate and put in table 5.3: coil admittance $Y_L = I_L / V$, coil active $G = R \cdot Y_L^2$ ($R = P / I_L^2$), reactive B_L ($Y_L = \sqrt{G_L^2 + B_L^2}$) conductivities, capacitor reactive conductivity $B_C = I_C / V$, circuit reactive conductivity $B = B_L - B_C$, coil phase shift angle φ_L ($tg\varphi_L = (B_L / G)$), circuit phase shift angle φ ($tg\varphi = (B / G)$). Draw three vector diagrams using the data from table 5.3. Losses in capacitors are negligible, that's why the capacitor phase shift angle should be $\varphi_C = -\pi / 2$.

Report on work

The name and purpose of the work. Homework – the calculation of the circuit. Schematic diagram of the investigated circuit (fig 5.11). Tables 5.2, 5.3. The vector diagrams. Conclusions.

Control questions

1. Write down the electrical status equation for the circuit with parallel connection of RLC -elements in vector form and draw the vector diagram for this circuit.
2. Draw conductivities calculated triangle for the circuit with parallel connection of RLC -elements and write down the corresponding expressions for it.
3. Explain what is it the active and reactive current constituents.
4. Draw powers calculated triangle for the circuit with parallel connection of RLC -elements and write down the corresponding expressions for it.
5. Give the definition of current resonance, write down the resonance condition and explain the resonance indication.
6. Give the definition of voltage resonance frequency, circuit wave resistance and explain the ways of resonance reaching.
7. What is the admittance of the circuit, phase shift factor and full power of the current resonance circuit? How current resonance is applied?
8. Draw the current resonance circuit frequency and phase characteristics.
9. Draw the resonance curves of currents of the current resonance circuit. Explain why the current at resonance is at minimum.

LABORATORY WORK 6

Investigation

of „wye” connection of three-phase circuit

Homework

Write down the phase voltages in complex form for the three-phase power source with linear voltage $V_L = 220\text{ V}$. To calculate phase active resistances, phase complex currents, neutral complex current for the three-phase consumer (fig.6.7), at given phase powers. Tasks variants are listed in the table 6.1.

Table. 6.1

| <i>Var</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------------------|----|----|-----|-----|-----|----|----|-----|-----|-----|
| <i>P_a, W</i> | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | 80 | 100 |
| <i>P_b, W</i> | 40 | 60 | 80 | 100 | 20 | 40 | 60 | 80 | 100 | 20 |
| <i>P_c, W</i> | 60 | 80 | 100 | 20 | 40 | 60 | 80 | 100 | 20 | 40 |

Elements of laboratory settings

Laboratory settings consist of the power supply *БП4822-2*, clamps terminal, board 3, measuring devices.

The elements of the board 2 are: consumers (lamps *L1-L9* ($220\text{ V}, 25\text{ W}$)),

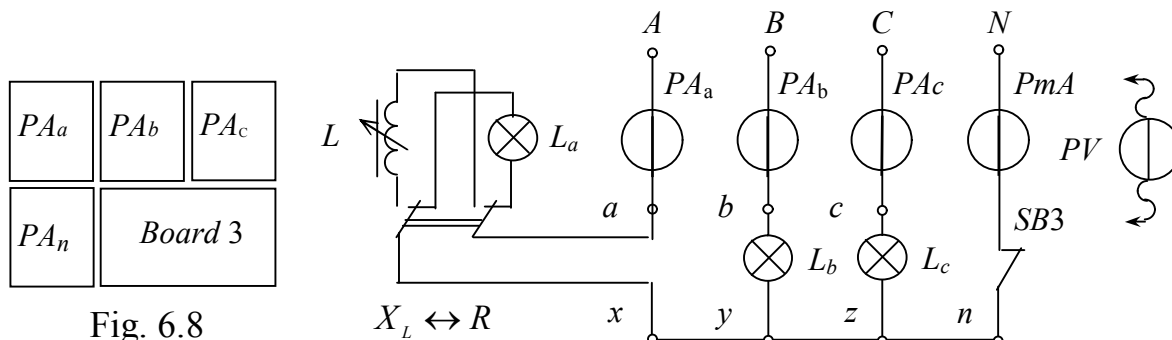


Fig. 6.8

Fig.6.9

phase switches $SB1, SB2$, neutral switch $SB3$, coil, switch « $X_L \leftrightarrow R$ ».

Measuring devices are: $PV(P\Omega)$ – multimeter *И4300* to measure voltage, options: $\langle \sim \rangle$, $\langle V \rangle$, $\langle 200\text{ V} \rangle$; PA – ammeters *Э536*, limit of measuring $\langle 0.5\text{ A} \rangle$; PmA – milliamperemeter, limit of measuring $\langle 200\text{ mA} \rangle$. The way of measuring devices placement is shown in fig. 6.8.

The work execution order

1. To collect the circuit (fig. 6.9) and connect it to the clamps A, B, C, N of the three-phase voltage power source $\langle 3 \sim 220\text{ V} \rangle$.

2. To investigate the circuit (fig. 6.9) with balanced loading $R_a = R_b = R_c = R_p$ ($SB1$ and $SB2$ closed, switch « $L \leftrightarrow \Pi$ » in position Π) with neutral ($SB3$ closed) and without neutral ($SB3$ open). To write down the results to the table 6.2.

Draw the vector diagram of currents using the data from table 6.2, line 1.

Table 6.2

| Measurements | | | | | | | | | | | |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|-------|
| $N\varnothing$ | V_A | V_B | V_C | V_a | V_b | V_c | I_a | I_b | I_c | V_{nN} | I_n |
| | V | V | V | V | V | V | A | A | A | V | mA |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |

3. To investigate the circuit (fig. 6.9) with non-balanced loading $R_a \neq R_b \neq R_c$ ($SB 1$ and $SB 2$ are open, switch « $L \leftrightarrow JI$ » in position JI) with neutral ($SB 3$ closed) and without neutral ($SB 3$ open). To write down the results to the table 6.3.

Draw the vector diagram of currents using the data from table 6.3, line 1.

Table 6.3

| Measurements | | | | | | | | | | | |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|-------|
| $N\varnothing$ | V_A | V_B | V_C | V_a | V_b | V_c | I_a | I_b | I_c | V_{nN} | I_n |
| | V | V | V | V | V | V | A | A | A | V | mA |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |

4. To investigate the circuit (fig. 6.9) with balanced loading $I_A = I_B = I_C$ ($SB 2$ closed, switch « $L \leftrightarrow JI$ » in position L) with neutral ($SB 3$ closed) and without neutral ($SB 3$ open). In order to balance the phase currents it is necessary to move the core in the coil. To write down the results to the table 6.4.

Table 6.4

| Measurements | | | | | | | | | | | |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|-------|
| $N\varnothing$ | V_A | V_B | V_C | V_a | V_b | V_c | I_a | I_b | I_c | V_{nN} | I_n |
| | V | V | V | V | V | V | A | A | A | V | mA |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |

Draw the vector diagram of currents using the data from table 16.4, line 1.

Report on work

The name and purpose of work. Homework – the calculation of the circuit. Schematic diagram of the investigated circuit (fig 6.9). Tables 6.2, 6.3, 6.4. The vector diagrams. Conclusions.

Control questions

1. Give the definition of three-phase electromotive force system. Explain how we can receive it. When the system will be balanced? Draw the vector diagram of three-phases electromotive forces.

2. Explain what is called the order of phase changing and how we can change it. What load we call balanced and write down the condition of balanced load.

3. Write down the expressions of instantaneous phases electromotive forces and their effective value complexes.

4. Explain the main types of source and consumer connection in three-phase system.

5. Write down the expressions of active, reactive and total power of three-

phase system using phase voltages and currents and line voltages and currents.

6. Write down the expressions of active, reactive and total power of three-phase system using line voltages and currents.

7. Draw the three-phase source „wye” connection and mark the phases and line voltages and currents.

8. Write down the relationships between effective values of phase and line voltages and currents for „wye” connection.

9. Explain the neutral role in three-phase system. How can the current be defined in it?

10. Write down how we can define the complex line voltages for the known complex phase voltages for the consumers’ „wye” connection.

11. Explain what voltage is called neutral bias voltage and how we can define it.

12. Draw the phase and line voltages for the consumers „wye” connection at vector diagram. What is the phase shift angle for them?

13. Explain how the three-phase circuit with non-balanced „wye” connected load can be calculated.