MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

Zaporizhzhia Polytechnic National University

METHODICAL GUIDES

For laboratory works on course

«FUNDAMENTALS OF ELECTRICAL MEASUREMENT AND METROLOGY»

students towards the specialty
G3 Electrical Engineering
of all forms of learning

Part 2

2025

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CONTENTS

PREFACE

Methodical instructions contain descriptions of the three laboratory work on discipline «Fundamentals of electrical measurement and metrology»in accordance with the curriculum specialties Bachelor's Degree G3 Electrical Engineering and recommendations for their implementation.

Laboratory work containing brief theoretical information under the theme of work, objectives, recommendations for their implementation and test questions for better learning and verifying the student knowledge and skills.

For students of specialty G3 Electrical Engineering of all forms of learning.

1 LABORATORY WORK №5

Investigation of induction energy meters.

Aim of work: familiar with the structure and principle of induction meter, the methods of its inspection, investigation of error depending on load current meter.

Program of work.

The absence of self-driving and defining the threshold of sensitivity meter. Study of regulation counter. Check meter and determine its load curve. Processing of measurement results and ordering a report.

Short theoretical information.

The most common device for measuring power AC induction meter is a measuring tool with tangential type. The structure of the meter and switch circuit shown in figure 1.1 [1], and vector diagram - pas figure 1.2.

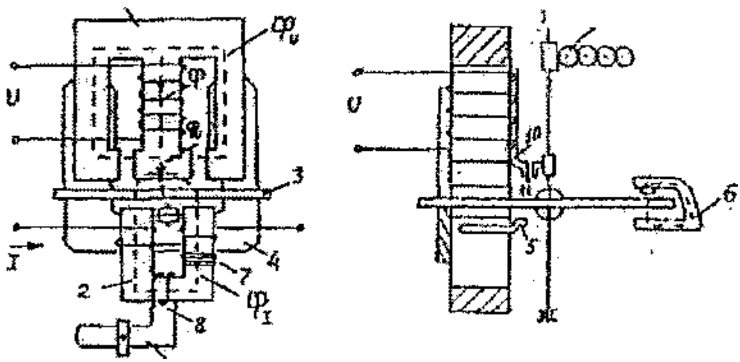


Figure 1.1 – Structure of the Induction Meter

Induction meter measuring mechanism consists of the following units and parts: Ш-shaped magnetic core and winding of voltage 1, П-shaped magnetic core 2 with magnetic winding current, aluminum disc 3 fixed to the axis, protypolyusu 4 by soft magnetic steel, steel snood 5 to create a compensation moment, the magnet 6 to create a braking torque, short-locked turns 7, additional windings 8, closed on wired resistor 9, plate with flag 10, made of soft magnetic steel, steel hook 11, the counting mechanism 12.

When unlocking a meter to the voltage U attached to the winding tension, winding creates a current I_U. which lags by a phase to an angle close to 90 ° due to the inductive coil resistance [2].

The current I_U creates a magnetic flow Φ average magnetic core rods I. The flow Φ is divided into two streams Φ_U and Φ_L; workflow Φ_U crosses disk 3 and focuses on magnetic and protypolyus through 4; Φ_L closes off flow through the side magnetic cores and a large part in creating a torque meter not. Flows Φ_U i Φ_L lagged current I_U at angles of α_U and α_L, respectively, and $\alpha_U > \alpha_L$ because it crosses through the disk and closes against the policy. When I switch on the load current creates a magnetic 2 in magnetic flux physics that drive and double-crosses through mahnitoprovid 2. The flow physics - behind the current I and the angle.Fu and magnetic flux crossing the disc physics, it is determined in EMF, so that the disc is a short leader, in disk flow eddy currents.The disc has a couple of forces that creates a torque moment of:

$$M_t = C \cdot f \cdot \Phi_U \cdot \Phi_I \cdot \sin\psi, \qquad (1.1)$$

where f - frequency of the alternating current network;

Ψ - the angle between the flows.

When working on a linear magnetic field magnetization curve have:

$$\Phi_I = k_1 \cdot I; \ \ \Phi_U = k_2 \frac{U}{Z_U} = k_2 \frac{U}{2\pi f L_U}, \qquad (1.2)$$

where L_U - inductance of the winding voltage; k1, k2 - a constant.

Substituting the value of a constant flux, we obtain

$$M_t = k \cdot U \cdot I \cdot \sin\psi\ . \qquad (1.3)$$

If $\beta = \psi + \varphi + \alpha_I > \frac{\pi}{2}$, then adjusting α_I, possible to ensure, that $\psi + \varphi = \frac{\pi}{2}$, scilicet, $\psi = \frac{\pi}{2} - \varphi$. That $\sin\psi = \cos\varphi$, and

$$M_t = k \cdot U \cdot I \cdot \cos\varphi = k \cdot P, \qquad (1.4)$$

where k – constant.

Equality $\psi = \frac{\pi}{2} - \varphi$ achieved by adjusting the angle α_I, by changing the number of short coils 7 on magnetic cores 2 and the change of resistance wire resistor 9. To drive a winding with uniform speed proportional power consumption, torque has to balanced by an equal M_g braking torque proportional speed drive. Deorbit time creates a permanent magnet field which crosses the disk. Number of revolutions of a disk [3]:

$$N = A \cdot Wn\,, \qquad (1.5)$$

where W_n - energy measured by the meter.

Coefficient A, numerically equal to the number of turns on (1kWt/hour), called the gear ratio meter. Gear Ratios counter points to his name plate. A value of the counter gear ratios, ie energy, accounted for 1 spin disc is called meter constant nominal Cн.

Nominal constant:

$$C_n = \frac{3600 \cdot 10^3}{A}\,, \qquad (1.6)$$

where 10^3, 3600 - conversion factor from kWt/hour to Wt/s.

The actual meter constant C_a is not equal to the nominal value of input current load is determined, so meter error depends on the load current

$$C_a = \frac{W_a}{N}\,. \qquad (1.7)$$

The impact of error makes the friction moment in a clearing mechanism and resistance of moving parts.Obviously, time will reduce the friction torque and included energy meter will be less valid. To compensate for this systematic error in additional torque (compensation).In this construction the moment the counter is created using five leash attached to the pole in the drive against the counter, through which the forks additional flow Φ_K. Transverse leash of radial direction arises additional torque that compensates for time friction [4].

When operating the meter equal compensatory time and moment of friction meter is broken and the disc may start rotating even when I_H=0, that's when energy consumption is not. This phenomenon is called self-driving. In his address in the box provided construction meter 10 and hook 11. Flag 10 magnetised flow Φ_K i, when the hook come to him, he holds it by a magnetic connection. Interaction force between boxes and hooks should be adjusted so that the meter was permissible limit of sensitivity.The limit of sensitivity - is the smallest normalized value of current in percentage of rated current at which the rotation starts at the counter $U = U_n$ and cosφ=1. For meters with accuracy class equal to 1,0, level of sensitivity must be not over 0,5%, when accuracy class is 2,5-1% [5].

Since the counter is integrating device, its accuracy is determined by the relative error

$$\delta\% = \frac{W_n - W_a}{W_a}100\% = \frac{C_n N - C_a N}{C_a N}100\% = \frac{C_n - C_a}{C_a}100\%, \qquad (1.8)$$

where W_n - energy is measured counter; W - real value of energy, defined by the testimony of exemplary devices; C - real counter constant.

Dependence of the error count of load current is called the loading curve.

Instruments and equipment

The list of devices and equipment is given in table 1.1

Table 1.1 – List of Instruments and Equipment

Name of device, equipment	Type of device, equipment	Accuracy class	basic characteristics
Induction meter	CO-H446	2,5	A=1200; U_n =220V; I_n =5...17A
Ammeter	Э59	0,5	0-2,5-5,0 A
Milliammeter	Э34	1,0	0-70 мА
Voltmeter	Э-378	1,5	0-250 V
Laboratory autotransformer ЛАТР	educational		
phase responsive device	-	-	

The task.

Collect scheme (Figure 1.2). After the switch to establish the nominal current cosφ = 1. To set cosφ = 1 rotate the shifter knob to the maximum evidence kilowatt hour meters. Preheat meter nominal current for 15 minutes.

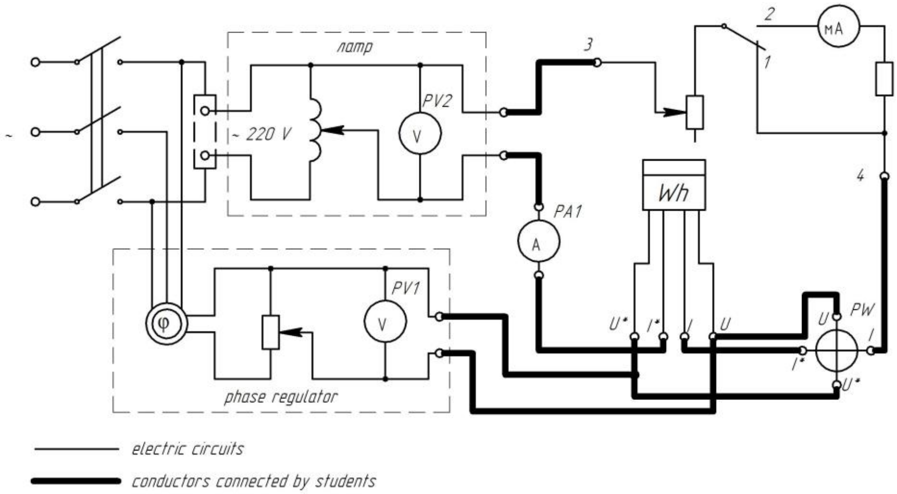


Figure 1.2 – Laboratory Setup Diagram

Check the lack of self-driving, for this set voltage 240 V at $I=I_n$ and by passing through a red label box end the current range switch S. If after this disc will perform no more than one rotation, the traverse is notand by passing through a red label box end the current range switch S. If after this disc will perform no more than one rotation, the traverse is not. Determine the limit of sensitivity meter, check for this voltage U=Un = 220 V and switch to position 2. Increase the current from 0 to, at which the disk begins to rotate counter. Limit of sensitivity will determine the formula

$$S = \frac{I_{tr}}{I_n} 100 .$$

Make a partial count verification of the following methods: kilowatt hour meters and stopwatch, with indications of which determine the real value of electricity, considered exemplary meter meter class accuracy is significantly crown meter accuracy which inspection of. Meter calibration should be carried out under standard conditions, that's at ambient temperature 20 °C – 3 °C, voltage Un ± 1%U, deviation from vertical not more than ± 1 and so on.

Meters calibration in this paper the method of kilowatt hour meters and stopwatch at a nominal voltage of 220 V cosφ=1 by determining the relative error count by (5.8) with current I = 20, 40, 60, 80 i 100 % from In= 5 A.

Be satisfied I= 0,2 I_n and record the readings - ammeter, kilowatt hour meters, voltmeters in table 5.2. To determine W stopwatch measure the length of time equal to approximately 50-60 s and count the number of revolutions N during this interval.Determine the time interval Δt, which corresponds to N, rotations, three times, with measured values of Δt and take the arithmetic mean of three measurements.

Results of measurements and calculations write in table 1.2.

Table 1.2 – Results of Measurements and Calculations

Measured				Calculated				
I, A	U, V	P_w, Wt	Δt, s	N, turn	$W_a = P_w \Delta t$	$W_n = C_n N$	$C_a = \frac{W_a}{N}$, Wt/turn	δ, %

Build the load curve meter and explain in writing the reasons for increase and decrease errors at each site.

Contents of the report of the laboratory work.

The contents of the laboratory work should include the topic, the aim of laboratory work, short theoretical information, laboratory setup scheme, filled table 1.1 and 1.2, the calculations, plots of graph $\delta = f(I)$, conclusions of laboratory work.

Control questions

1 What are the basic units of the induction meter and explain what forces create torque.

2 Under what conditions the disc rotates with uniform speed proportional power capacity?

3 What creates a braking torque acting on the disk? Why and how is it regulated?

4 What is the angle between the regulated flow of electromagnets range of current and voltage range?

5 What is required compensatory time? As he established and regulated?

6 What is a traverse count? How is it removed?

7 What is the limit of sensitivity of the counter?

8 How to determine the energy meter and considered a relative error count?

9 Explain the nature of the load curve counter.

2 LABORATORY WORK №6

Measured resistance DC bridge.

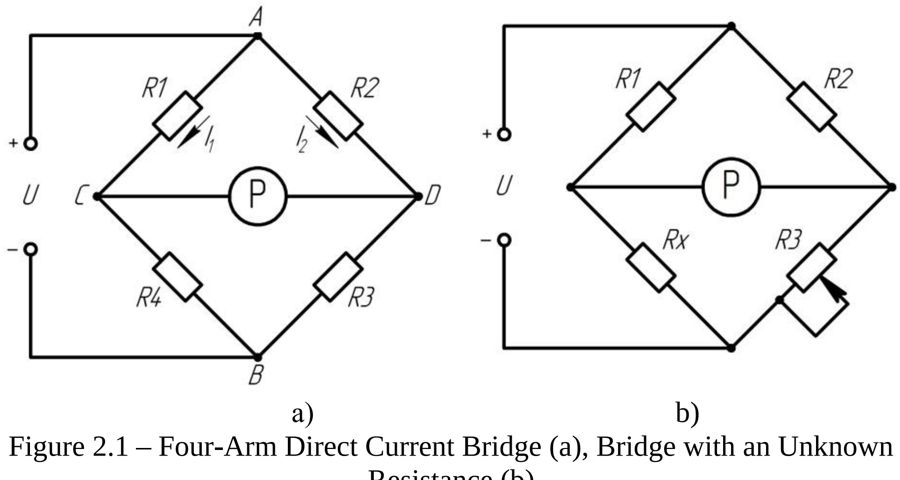
Aim of work: familiar with the bridge resistance measurement techniques and master the technique of measurement.

Program of work.

Single measurement bridge resistances within the definition of average values and the resistivity of the material guide. Measurement of double bridge resistances within small values. Processing of measurement results and ordering a report.

Short theoretical information.

The scheme is shown in figure 2.1, a bridge or bridge DC Uitstona; points A, B, C and D - top of the bridge; range between adjacent vertices A and C, and D, etc. - behind the bridge, and the code between the opposite vertices A and B. C and D - the diagonal. In one of the diagonals submitted voltage U, and the second turn on the measuring device [1].



a) b)

Figure 2.1 – Four-Arm Direct Current Bridge (a), Bridge with an Unknown Resistance (b)

Bridge scheme has the following property: if $U_{BC} = U_{BD}$, in the current measuring diagonally missing. This state of equilibrium is called the bridge, and the equation $U_{BC} = U_{BD}$ equilibrium condition.

$$U_{BC} = I_1 \cdot R_4; \;\; U_{BD} = I_2 \cdot R_3; \;\; I_1 = \frac{U}{(R_1 + R_4)}; \;\; I_2 = \frac{U}{(R_2 + R_3)}.$$

Then

$$R_2 \cdot R_4 = R_1 \cdot R_3. \tag{2.1}$$

This equation balance bridge DC. Properties bridge circuits are widely used for measuring resistances. If instead one of the resistors, for example instead of R_4 (figure 2.1 a) connect a resistor of unknown resistance in Rh (figure 2.1, b), one of the other resistors, for example R_3, make it adjustable by adjusting R_3, cities can lead to equilibrium state. Then

$$R_x = R_3\left(\frac{R_1}{R_2}\right). \tag{2.2}$$

From (2.2) shows that the measurement result does not depend on the applied voltage or current in a circle. Thus, the balanced bridge circuit provides very high accuracy measurement.

Bridge circuits are also used to convert resistance to voltage in the unbalanced mode.If the unbalanced bridge, the current in the measuring diagonal

$$I_P = \frac{U(R_2R_4 - R_1R_3)}{R_P(R_2 + R_3)(R_1 + R_4) + R_2R_3(R_1 + R_4) + R_1R_4(R_2 + R_3)} \tag{2.3}$$

At constant voltage power supply and resistances R_1,R_2,R_3 current in the diagonal, and hence the voltage drop

$$U_{CD} = f(R_4). \tag{2.4}$$

Most such schemes are used to convert electric quantities - displacement, strain, temperature and so on at their electrical measurements. The device P, in unstable bridges hraduyuyetsya in measuring values [6].

Measurement error balanced resistance bridge depends on the error model calibration resistorsR_1,R_2,R_3 that's the degree of error and the error due to incomplete equilibration of the bridge.

Uncertainty due to incomplete equilibration of the bridge depends on the sensitivity of bridge circuits.

The sensitivity of the bridge - ratio increased deflection measuring Δa to the relative resistance change:

$$S_M = \Delta\alpha \Big/ \frac{\Delta R}{R} \qquad (2.5)$$

The sensitivity of the bridge is a product of the sensitivity of the measuring circuit for measuring sensitivity, that's

$$S_M = \frac{\Delta\alpha}{\Delta R / R} = \frac{\Delta I}{\Delta R / R} \cdot \frac{\Delta\alpha}{\Delta I} S_{CX} S_B . \qquad (2.6)$$

The sensitivity of bridge circuits depends on the ratio of shoulder bridge, the internal resistance measuring device and power supply voltage value. If the measuring device is a voltmeter or galvanometer of high resistance, the maximum sensitivity of the bridge will have the

$$R_2 \approx R_3 ;\ R_1 \langle\langle R_2 ;\ R_2 \rangle\rangle R_x . \qquad (2.7)$$

In small resistance galvanometer sensitivity will be maximum at

$$R_3 < R_2 ;\ R_1 < R_2 ;\ R_2 > R_x . \qquad (2.8)$$

To ensure high sensitivity of the bridge when measuring the resistance in a wide range in standard bridges can change the resistance arms in a wide range [7].

Shoulder R_x in balanced bridge circuit (figure 6.1, b) is executed as many stores decade resistance of $10 \cdot 100$ Ом; $10 \cdot 10$ Ом; $10 \cdot 1$ Ом; $10 \cdot 0{,}1$ Ом; $10 \cdot 0{,}01$ Ом and is called the comparison arm. Shoulders R_1 and R_2, (each consisting of resistances 10, 10^2, 10^3, 10^4 ohms) are called shoulders attitude.

A scheme called the four shoulder bridge. These bridges provide high accuracy measurement of relatively large resistance of 10 to 10^5 ohms. Taking these bridges resistances between 1 and 10 ohms of error amounts to 1% and above, and such bridges measuring less than 0,1 ohm resistance over large errors do not. This case, transitional support contacts and supports the connecting wires are measurable levels of resistance. For measurement of small resistances in the range of 10^{-6} to 10 ohms used double bridges DC.

Double Bridge (bridge Thomson) shown in figure 2.2. Measured resistance R_x clamp should have four - two current used to switch the R_x range in power bridge, and two potential between which the measured resistance. The same clip has an exemplary resistor R_n.Transitional support current terminals are in range of a connector wire R_0 and wires that go to the power source.Transitional support potential clamp and corresponding interconnections of the wires are turned on sequentially supports shoulders bridge R_1, R_2, R_3, R_4 to exclude the influence of transient resistance and resistance wire interconnections bearing shoulder bridge. R_1, R_2, R_3, R_4 are selected by double bridges greater than 10 ohms.

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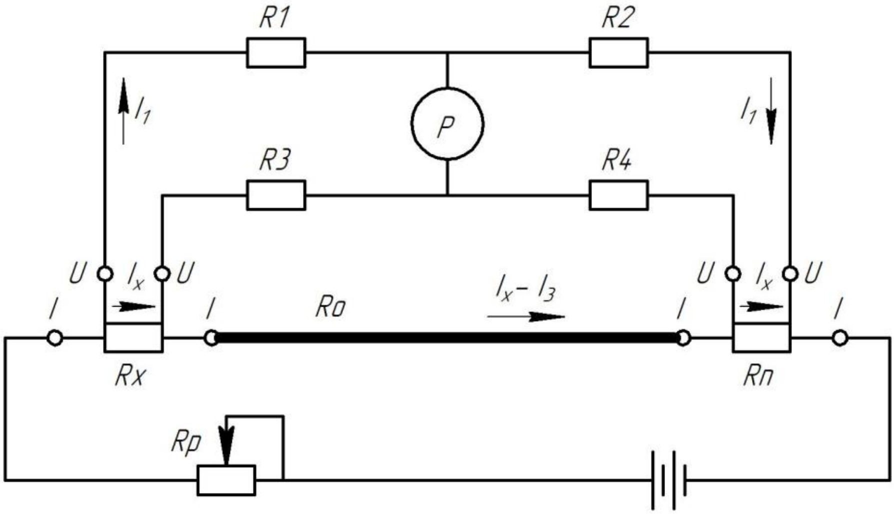

Figure 2.2 – Six-Arm Bridge

At balance dual bridge when $U_{аб}$=0, can make the following equations:

$$I_1R_1 - I_xR_x - I_3R_3 = 0;$$
$$I_1R_2 - I_xR_4 - I_3R_4 = 0; \quad (2.9)$$
$$I_3(R_3 + R_4) - (I_x - I_3)R_0 = 0.$$

From these equations follows

$$R_x = \frac{R_1}{R_2}R_н + \frac{R_4R_0}{R_3 + R_4 + R_0}\left(\frac{R_1}{R_2} - \frac{R_3}{R_4}\right). \quad (2.10)$$

If

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}, \tag{2.11}$$

Then

$$R_x = \frac{R_1}{R_2} R_n. \tag{2.12}$$

To carried out the condition (2.11), double bridges are performed so that each pair of resistance changes at once, or by mechanical coupling of resistors handle plug or permutation Male stores. For better implementation of equality (2.11), resistor Ro should have little resistance;so do it as a piece of copper bus [8].

Errors measuring of dual resistance bridge measurement error than average resistance chotyrohplechym bridge and can reach several percent.

Instruments and equipment.

Universal instrument P4833, designed to measure resistance, voltage and EMF constant and verification technology for example.

Accuracy class 0,1; power supply: 220V; 50 Hz

Resistances set consists of 5 decades: a degree of resistance 100; 10; 1; 0,1; 0,01 Ohm - they are back comparison. Shoulders attitude made as delytelya, resistors which are situated on the decade switches 10^3 , 10^2, ...10^{-3},10^{-4}. Zero - an indicator is a galvanometer, with the on button «rude», «exactly». buttons MO-2, MO-4 - code work. Clips T1, T2, П1, П2 - Connectivity resistance. Button «Сеть» to connect the appliance.

The task.

Resistance measurement of 102 to 106 Ohm.

Turn gauge measuring the resistance leaders to clamp «П1» and «П2». Handles decade switches set resistance value resistor. Click the « MO-2» and «Г».

Turn the unit, turn on the machine, click the «Сеть». Set the arrow on the galvanometer zero rotation handles decade switches shoulders comparison, initially - when button is «rough», then - «Exactly».

Define resistance resistors $R_X = NR_M$ Ohm, where N - the ratio of resistances shoulders attitude. R_M - Resistance Value shoulders comparison. Remove the Power to install controls in the home position switch stand.

Measuring resistance 10^{-4} to 10^2 Ohm. Enable resistor to clamp «T1», «П1», «П2», «T2»; click the «MO-4» and «Г», set value of resistance, Switch the appliance, set the arrow galvanometer to zero. Determine $R_x = NR_M$ Drop device.

Give the results of measurements and calculations in table 2.1.

Table 2.1 – Results of Measurements and Calculations

Type resistor	Measured		Calculated	
	N	R_x, Ohm	Δ, Ohm	δ, %

Contents of the report of the laboratory work.

The contents of the laboratory work should include the topic, the aim of laboratory work, short theoretical information, laboratory setup scheme (fig. 2.1, 2.2), filled table 2.1, the calculations, conclusions of laboratory work.

Control questions.

1 Single-bridge circuit to give DC and formulate the equilibrium condition of the bridge.

2 Why do small dimension single error resistance bridge great?

3 Establish a scheme of double bridge and write equations for determining the measured resistance.

4 Put four methods of measurement of resistance with a single bridge.

5 What is the error of measurement of resistance bridge method?

6 What is the sensitivity of the bridge?

7 What is the condition of maximum sensitivity of the bridge when it is switched on diagonal voltmeter, ammeter?

8 For what used unbalanced bridge circuit? How to get results by measuring unbalanced?

9 Classification of bridges.

3 LABORATORY WORK №7

Measurement of electrical quantities by a digital oscilloscope.

Aim of work: the study of the structure, the principle of the digital oscilloscope OWON PSD 5022S and get the skills to measure electrical quantities.

Short theoretical information.

The oscilloscope OWON PSD 5022S is intended for research of electric signals by their visual observation on a liquid crystal display and measurement of their amplitude and time parameters. The oscilloscope can be used for laboratory and shop conditions, as well as for research and repair work [9].

General Information: record length of 5,000 points for each channel; reading-out with the cursor; twenty automatic measurement functions; autoscale function; color liquid crystal display of high resolution and high contrast; storage and recall waveforms; automatic setting function provided capable of fast setting; multiple-waveform calculation function; built-in FFT function; perform detecting the average and peak values of the waveform; digital real-time oscilloscope; edge, video and Alternating triggering function; RS232 or USB communication ports; different continuous displaying time.

Warning! In order to avoid suffering from the electric shock, please keep your finger behind the safety guard ring of the probe body during the operation. In order to protect you from suffering from the electric shock during your using the probe, do not touch the metal part of the probe tip when the probe is connected to the power supply. Before making any measurements, please connect the probe to the instrument and connect the ground terminal to the earth [10].

Before starting measurements, connect the device to a 220V power supply. The oscilloscope is activated by the «POWER» button on the upper part of the device housing (Fig. 3.1).

The instrument carries out all self-check items and shows the prompt «Press any Key Enter the Operating Mode».

Table 3.1 lists the controls and indications for the front panel of the oscilloscope (Fig. 3.2).

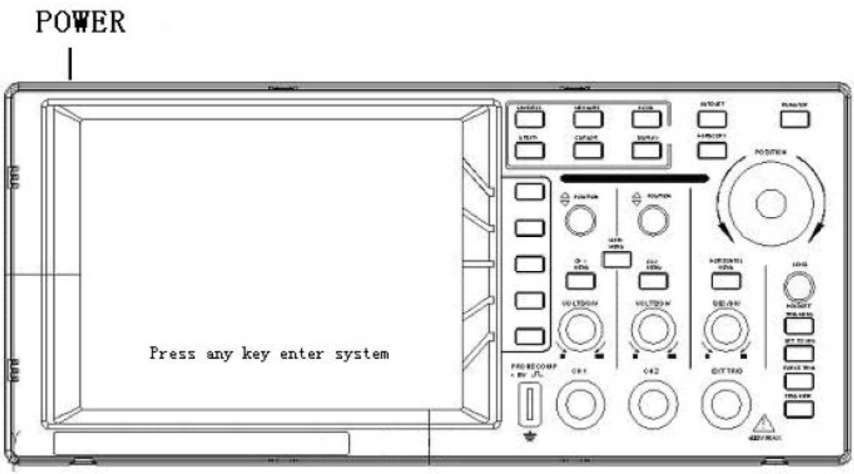

Figure 3.1 – The Front Panel of a PDS series Oscilloscope

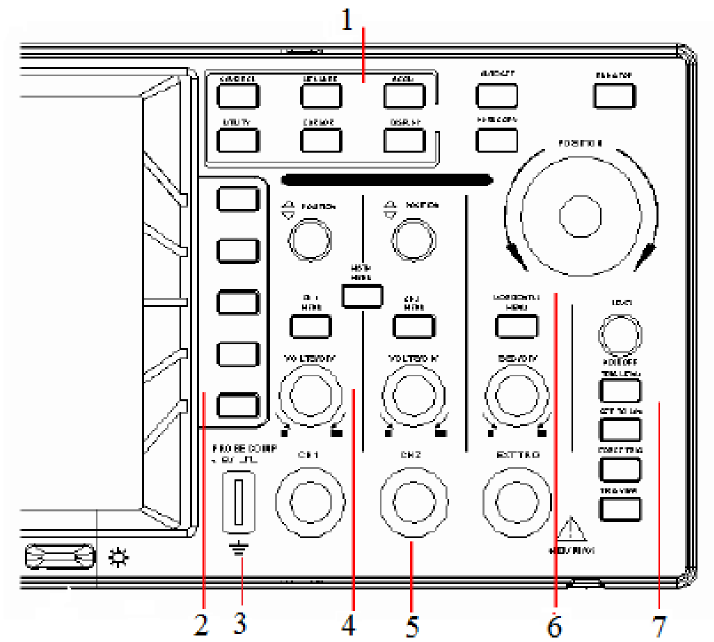

Figure 3.2 – Explanatory Drawing for Operations of the PDS series Oscilloscope

Table 3.1 – List of Control and Indication Elements on the Oscilloscope's Front Panel

Marking	Function
1	Function Buttons
2	Adjustment Menu Selection (F1 – F5)
3	Connector for compensation of the probe (Fig. 1.3)
4	Vertical Control (5 V…5mV)
5	Connector (CH1, CH2)
6	Horizontal Control (Position)
7	Trigger Control

Figure 3.3 – Connection of the Probe

Press the «UTILITY» button to get access to the «FUNCTION» menu and push down F2 the menu selection button to call out the function «Recall Factory». The default attenuation coefficient set value of the probe in the menu is 10X, shown as Fig. 3.4.

The list of elements for setting the measuring channel is shown in Table 3.2.

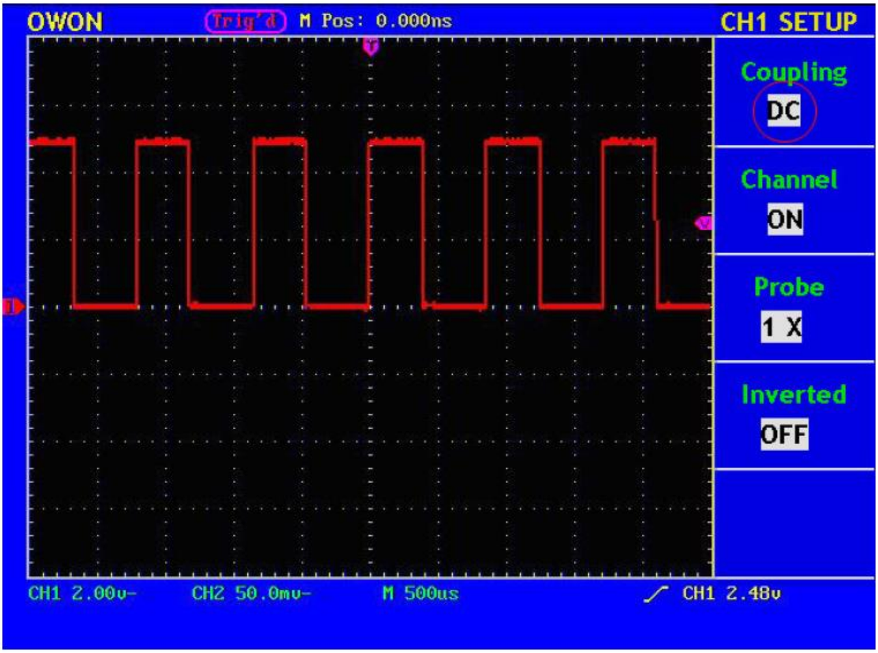

Figure 3.4 – DC Coupling Oscillogram

Table 3.2 – List of Elements for Configuring the Measurement Channel

Function Menu	Setting	Description
Coupling	AC DC	Block the DC component in the input signal. Unblock the AC and DC components in the input signal.
Channel	OFF ON	Close the measurement channel. Open the measuring channel.
Probe	1X 10X 100X 1000X	Choose one according to the probe attenuation factor to make the vertical scale reading accurate.
Inverted	OFF ON	The wave form is displayed normally. Initiate the wave form inverted function.

Setting Channel Coupling

Taking the Channel 1 for example, the measured signal is a square wave signal containing the direct current bias. The operation steps are shown as below: press the CH1 MENU button and call out the CH1 SETUP menu.

Press the F1 menu selection button and select the Coupling item as «AC»to set the channel coupling as ac mode, under which the direct current component in the signal will be blocked. Then, press the F1 menu selection button again and select the Coupling item as «DC», setting the channel coupling as DC mode, under which both dc and accomponents in the signal will be unblocked.

Press the F2 menu selection button and select the Channel as OFF, with Channel 1 switched off. Press F2 menu selection button again, select the channel as ON, with Channel 1 is switched on.

Press the F3 menu selection button and select 1X for the probe. To display the signal oscilloscope on the correct scale, you must adjust the relief factor of the probe in the measuring channel settings menu. When using a probe with a 1: 1 loosening, it is necessary to select a 1X installation.Wave form inverted: the displayed signal is turned 180 degrees against the phase of the earth potential. Press the F4 menu selection button and select ON in the Inverted. The wave form inverted function is initiated. Press the F4 menu selection button again and select OFF for Inverted item. The function of wave form inverted is closed off.

Perform Mathematical Manipulation Function (Table 3.3).

Press the MATH MENU button and call out the WAVE MATH menu. Press the F3 menu selection button and choose CH1+CH2. The green calculated wave form M is displayed in the screen; press the F3 menu selection button again, the wave form M is closed off (Fig. 3.5).

Table 3.3 – List of Mathematical Operations of the Oscilloscope

Setting	Description
CH1-CH2	Subtract the Channel 2 wave form from the Channel 1 wave form.
CH2-CH1	Subtract the Channel 1 wave form from the Channel 2 wave form.
CH1+CH2	Add the Channel 1 wave form to the Channel 2.

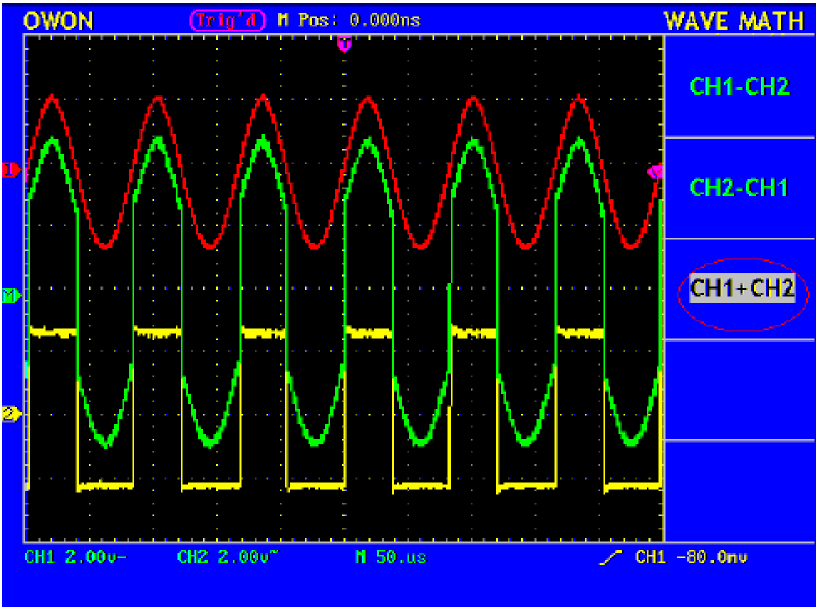

Figure 3.5 – Wave Form resulted from CH1 +CH2 Mathematical Manipulation

The .VERTIVAL POSITION knob is used to adjust the vertical positions of the wave forms of all Channels (including those resulted from the mathematical operation). The analytic resolution of this control knob changes with the vertical division.

The VOLTS/DIV knob is used to regulate the vertical resolution of the wave forms of all channels (including those obtained from the mathematical manipulation), which can determine the sensitivity of the vertical division with the sequence of 1—2—5. The vertical sensitivity goes up when the knob is rotated clockwise and goes down when the knob is rotated anticlockwise.

When the vertical position of the channel wave form is adjusted, the screen shows the information concerning the vertical position at the lower left corner HORIZONTAL POSITION knob: this knob is used to adjust the horizontal positions of all channels (include those obtained from the mathematical manipulation), the analytic resolution of which changes with the time base.

SEC/DIV knob: it is used to set the horizontal scale factor for setting the main time base or the window.

HORIZONTAL NENU button: with this button pushed down, the screen shows the operating menu

Instruments and equipment.

The list of devices and equipment is given in table 3.4

Table 3.4 – List of Instruments and Equipment

Name of device, equipment	Type of device, equipment	Accuracy class	basic characteristics
Induction meter	CO-H446	2,5	A=1200; U_n =220V; I_n =5...17A
Ammeter	Э59	0,5	0-2,5-5,0 A
Milliammeter	Э34	1,0	0-70 мА
Voltmeter	Э-378	1,5	0-250 V
Laboratory autotransformer	educational		
phase responsive	-	-	

The task.

Collect scheme (Fig. 3.6). After the switch to establish the nominal current cosφ = 1. To set cosф = 1 rotate the shifter knob to the maximum evidence kilowatt hour meters.

At the instruction of the teacher, change the position of the knob of the controller. According to the oscilloscope graphs of voltage and current signals, find out at which angle the voltage and current are shifted from each other, calculate the measured power according to the oscilloscope, compare the calculated power with the value measured by the watt meter.

Results of measurements and calculations write in table 3.5.

Voltage and current are shifted by phase at the angle φ (Fig. 3.7) $\varphi = ((t_2 - t_1) \cdot 360°)/T = (t_2 - t_1) \cdot 360° \cdot f$, where T – period of measured signal, sec; f = 1/T – frequency, Hz.

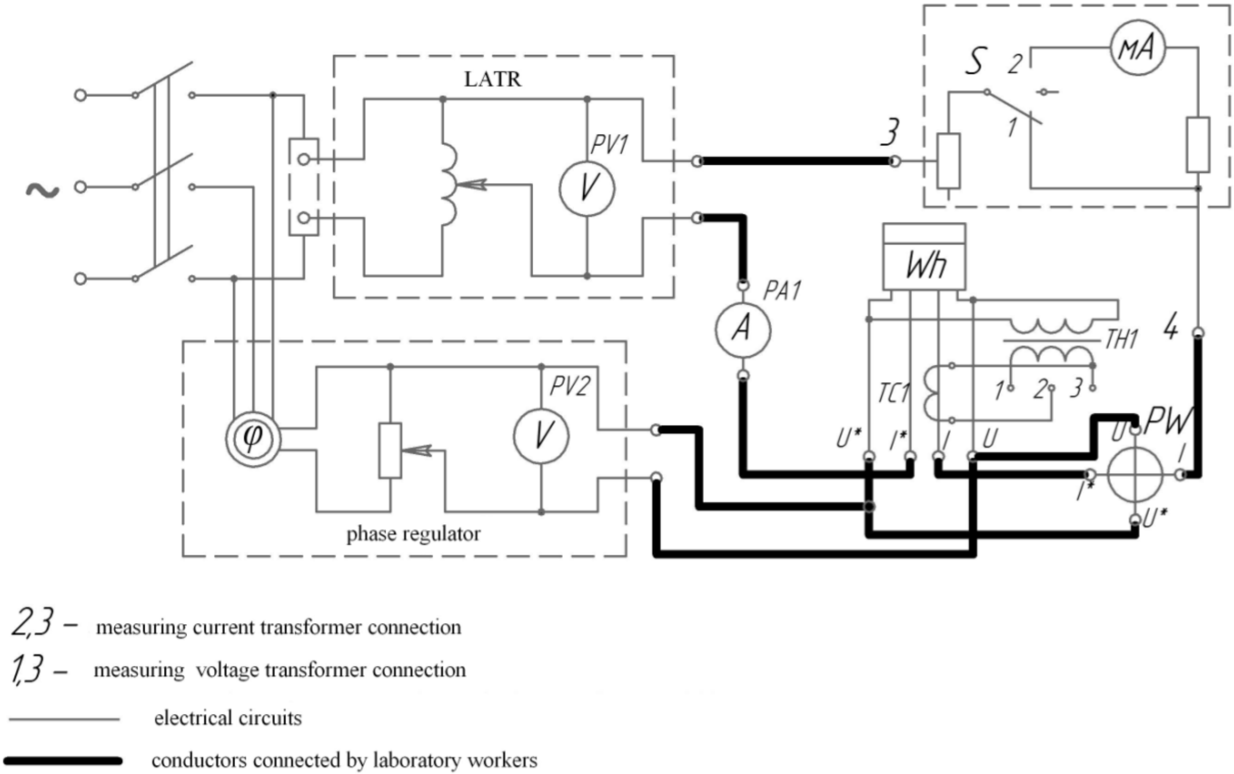

Figure 3.6 – Scheme of laboratory installation

Table 3.5 – Results of Measurements and Calculations

Measured					Calculated				
I, A	U, V	P_w, Wt	Δt, sec	N, turn	φ, rad	i_m, A	u_m, V	p, Wt	P_{Wh}, Wt

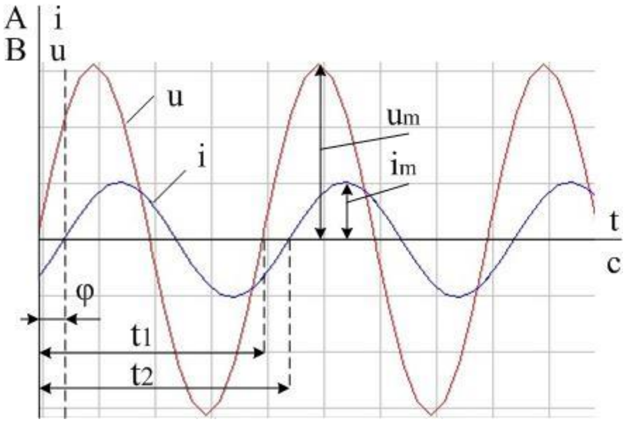

Figure 3.7 – Graphics of measured typical voltage and current signals

Instantaneous values of voltage, current and instantaneous power are determined by the relationships:

$$p = ui, \quad u=U_m \sin(\omega t), \quad i=I_m \sin(\omega t-\varphi).$$

Active power is determined from the ratio

$$P=UI\cos\varphi, \; U = U_m / \sqrt{2}, \; I = I_m / \sqrt{2}.$$

Power measured by the induction counter

$$P_{Wh} = N/(A\cdot\Delta t),$$

where N - number of revolutions of the counter, turn;

A - transfer number of the counter equal to the number of turns per unit of energy (1kWt h) and is indicated on its shield;

Δt - time of implementation of N rotations of the disk of the counter, sec.

Contents of the report of the laboratory work

The contents of the laboratory work should contain the subject, the purpose of the laboratory work, the short theoretical information, filled in tables 2.1 and 3.1, the scheme of the laboratory installation, photos of the screen of the oscilloscope, which contains images of the measured electric signals, an oscillogram pattern indicating the values used to calculate the measured power, calculations, conclusion.

Control questions

1 Explain the concept of quantization and sampling.

2 Bring a generalized block diagram of a digital meter.

3 Explain the concept of analog-digital conversion.

4 Basic metrological characteristics of ADCs and digital devices

5 Digital Meter Errors.

6 Explain the phenomenon of phase shift.

7 Explain the procedure for connecting and measuring a particular electric value with the digital oscilloscope OWON PSD 5022S.

8 Explain how to determine the measured value according to the data of the digital oscilloscope OWON PSD 5022S.

9 Explain how to change the horizontal and vertical position of measured signals.

10 Explain the sequence of actions for setting the measuring channel of the digital oscilloscope OWON PSD 5022S.

11 Name the mathematical operations of the digital oscilloscope OWON PSD 5022S.

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