PLAN OF THE LECTURE

1. Connection of load phases by triangle.

Power of three-phase electrical circuit.

3. Power measurement in a three-phase system.

Glossary

Symmetric and asymmetric load. The load is symmetrical if it is uniform and uniform. The load is unbalanced if at least one of the conditions is not met.

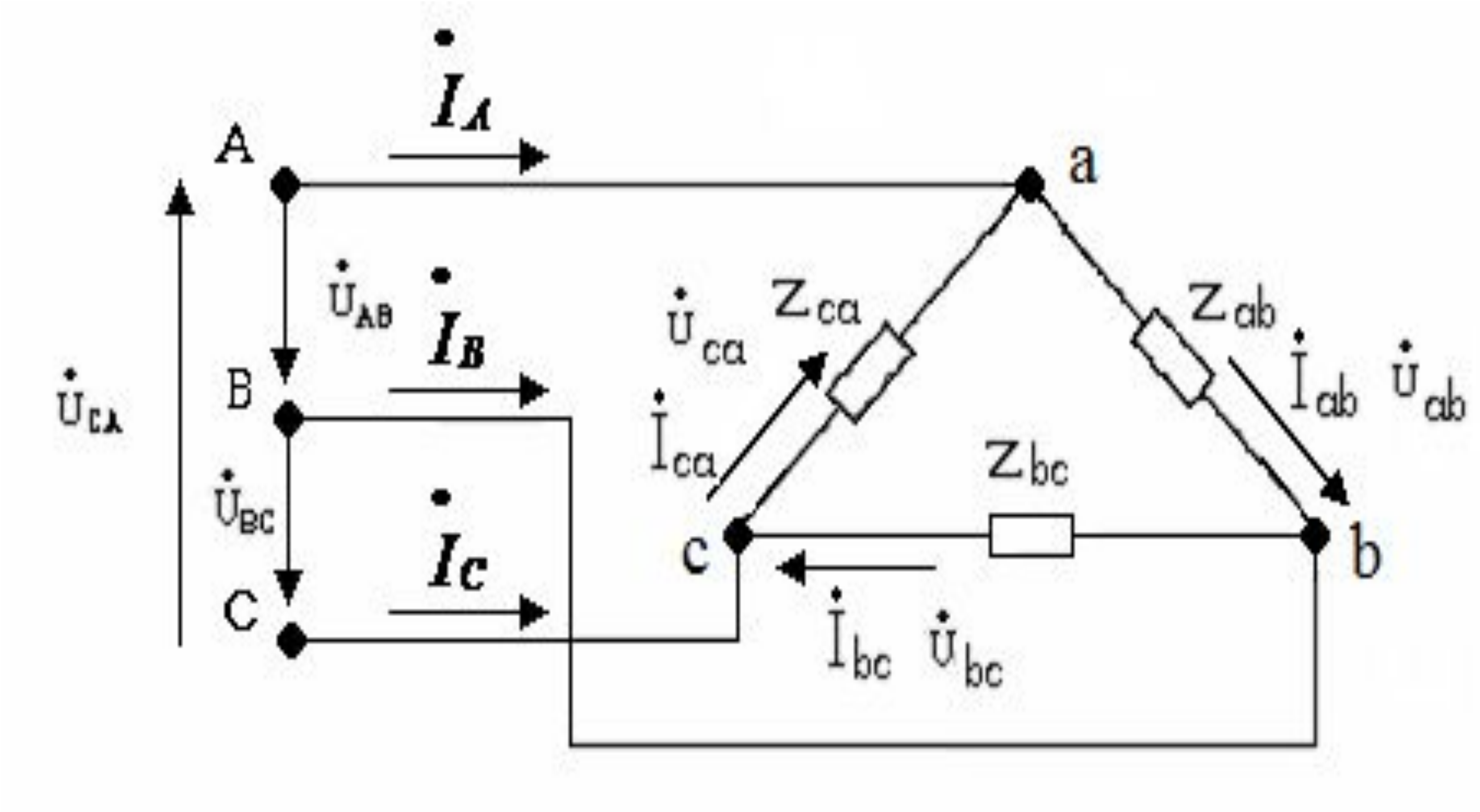
Three-phase system power measurement:

A) Single wattmeter method when a single wattmeter is used

B) Two wattmeter method when two wattmeters are used

C) Three wattmeter method when three watt meters are used.

Connection of load phases by triangle.



$\dot{I}_A, \dot{I}_B, \dot{I}_C$ – linear currents,

$\dot{I}_{ab}, \dot{I}_{bc}, \dot{I}_{ca}$ – phase load currents,

$\dot{U}_{AB}, \dot{U}_{BC}, \dot{U}_{CA}$ – linear voltage of a source

$\dot{U}_{ab}, \dot{U}_{bc}, \dot{U}_{ca}$ – phase voltages of a source.

If resistance of linear conductors is not taken into account, Rcon = 0, then

$$\dot{U}_{ab} = \dot{U}_{AB};$$

$$\dot{U}_{bc} = \dot{U}_{BC};$$

$$\dot{U}_{ca} = \dot{U}_{CA},$$

i.e. $U_{\Phi} = U_{\Lambda}$

and currents in line wires

$$\dot{I}_A = \dot{I}_{ab} - \dot{I}_{ca};$$

$$\dot{I}_B = \dot{I}_{bc} - \dot{I}_{ab};$$

$$\dot{I}_C = \dot{I}_{ca} - \dot{I}_{bc};$$

$$\dot{I}_A + \dot{I}_B + \dot{I}_C = 0;$$

где

$$\dot{I}_{ab} = \dot{U}_{ab} / Z_{ab};$$

$$\dot{I}_{bc} = \dot{U}_{bc} / Z_{bc};$$

$$\dot{I}_{ca} = \dot{U}_{ca} / Z_{ca};$$

Symmetric loading

or $$Z_{ab}=Z_{bc}=Z_{ca}=ze^{j\phi}$$

1. $z_{ab}=z_{bc}=z_{ca}=z$ - identical loading;
2. $\varphi_{ab}=\varphi_{bc}=\varphi_{ca}$ - uniform loading.

Let the load be symmetrical and the following condition is met:

$$R_{ab}=R_{bc}=R_{ca}$$

$$\varphi_{ab}=\varphi_{bc}=\varphi_{ca}=0$$

To draw a vector diagram of voltages and currents, calculate phase currents

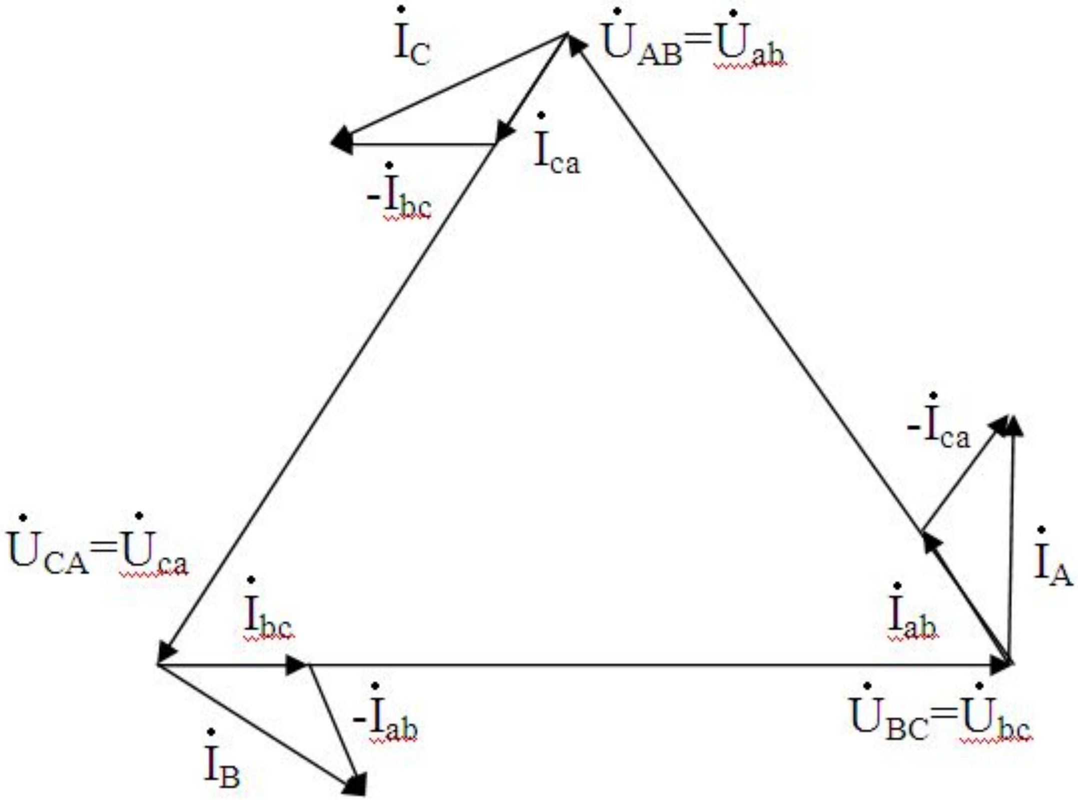
$$\dot{I}_{ab} = \frac{\dot{U}_{ab}}{Z_{ab}} = \frac{\dot{U}_{AB}}{Z_{ab}} = \frac{U_{л} e^{j30^{\circ}}}{R_{ab}} = I_{ab} e^{j30^{\circ}}$$

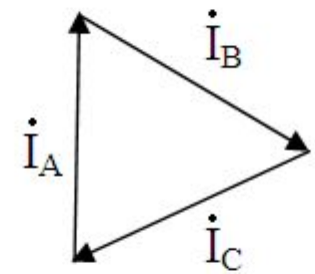
$$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{Z_{bc}} = \frac{\dot{U}_{BC}}{Z_{bc}} = \frac{U_{л} e^{-j90^{\circ}}}{R_{bc}} = I_{bc} e^{-j90^{\circ}}$$

$$\dot{I}_{ca} = \frac{\dot{U}_{ca}}{Z_{ca}} = \frac{\dot{U}_{CA}}{Z_{ca}} = \frac{U_{л} e^{j150^{\circ}}}{R_{ca}} = I_{ca} e^{j150^{\circ}}$$

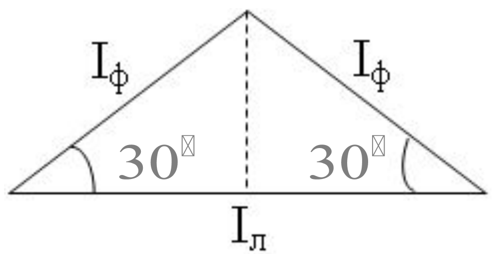
$$\dot{I}_{A} = \dot{I}_{ab} - \dot{I}_{ca}; \dot{I}_{B} = \dot{I}_{bc} - \dot{I}_{ab}; \dot{I}_{C} = \dot{I}_{ca} - \dot{I}_{bc}$$

Vector diagram





$\dot{I}_A+\dot{I}_B+\dot{I}_C=0$



$$\frac{I_{л}}{2} = I_{ф}\cos 30^\circ = I_{ф}\frac{\sqrt{3}}{2}$$

$$I_{л} = I_{ф}\sqrt{3}$$

Thus, under symmetrical load, the vectors of linear currents form an equilateral triangle and the bond between linear and phase currents is determined by the relation:

$$I_л = \sqrt{3} I_ф$$

Asymmetrical loading

$$\mathbf{R_{ab} > R_{bc} > R_{ca}}$$

$$\varphi_{ab} = \varphi_{bc} = \varphi_{ca} = \varphi = 0$$

$$\dot{I}_{ab} = \frac{U_л e^{j30^0}}{R_{ab}} = I_{ab} e^{j30^0}$$

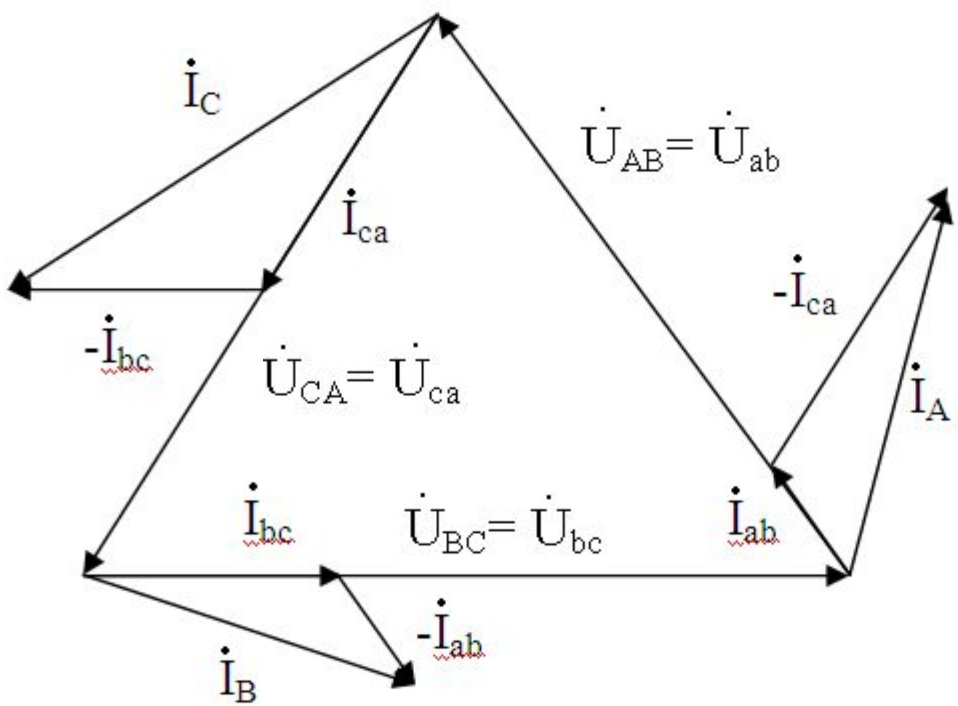
$$\mathbf{I_{ab} < I_{bc} < I_{ca}}$$

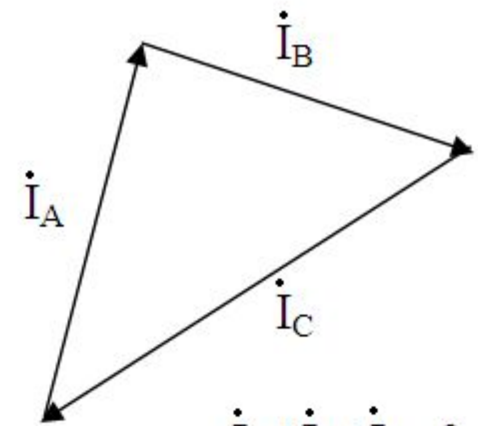
$$\dot{I}_{bc} = \frac{U_л e^{-j90^0}}{R_{bc}} = I_{bc} e^{-j90^0}$$

$$\dot{I}_{ca} = \frac{U_л e^{j150^0}}{R_{ca}} = I_{ca} e^{j150^0}$$

$$\dot{I}_A = \dot{I}_{ab} - \dot{I}_{ca}, \dot{I}_B = \dot{I}_{bc} - \dot{I}_{ab}, \dot{I}_C = \dot{I}_{ca} - \dot{I}_{bc}.$$

Vector diagram





$\dot{I}_A + \dot{I}_B + \dot{I}_C = 0$

$I_л \neq I_ф$

$U_л = U_ф$

Power of three-phase electrical circuit.

The instantaneous power value of the three-phase system is equal to the sum of the power of the phases

$$p = p_A + p_B + p_C = u_A i_A + u_B i_B + u_C i_C$$

A three-phase system with a symmetrical load is a balanced system, i.e. its power is constant and independent of time.

Indeed, the instantaneous value of the active power of the three-phase symmetric system $p=p_A+p_B+p_C$, and the mean of the period

$$P=3U_{ph}I_{ph}\cos\varphi_{ph}.$$

$$P = UI\cos\varphi$$

$$Q = UI\sin\varphi$$

$$P = P_A + P_B + P_C$$

$$Q = Q_A + Q_B + Q_C$$

$$S = \sqrt{P^2 + Q^2}$$

In practice, it is common to express power through linear values of current and voltage $V_L = V$; $I_L = I$;

For symmetric loading

$$P = \sqrt{3} UI \cos\varphi$$

Respectively reactive power

$$Q = \sqrt{3} UI \sin\varphi$$

Total power

$$S = \sqrt{P^2 + Q^2} = \sqrt{3}UI$$

The power factor ***cosφ*** is determined by the formula

$$\cos\varphi = \frac{P}{\sqrt{3}\mathrm{UI}}$$

Measurement of active power

1. Way of one wattmeter.

At symmetric loading.

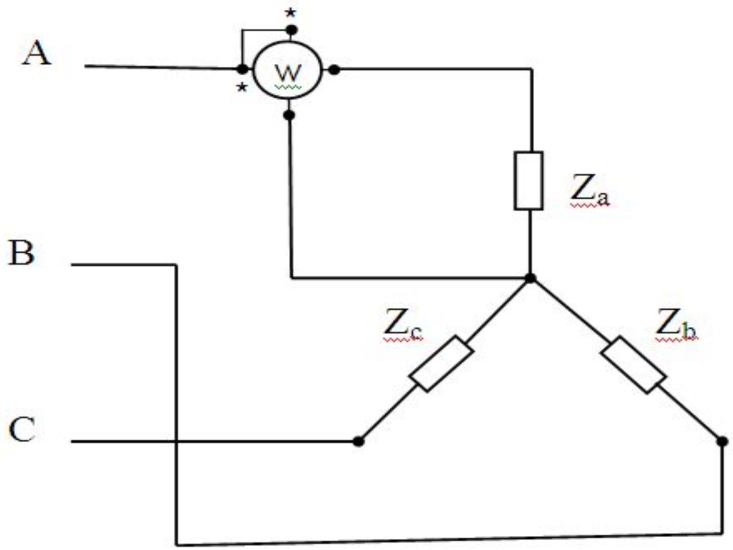
2. Way of two wattmeters.

At three-wire non-symmetrical load

3. Way of three wattmeters.

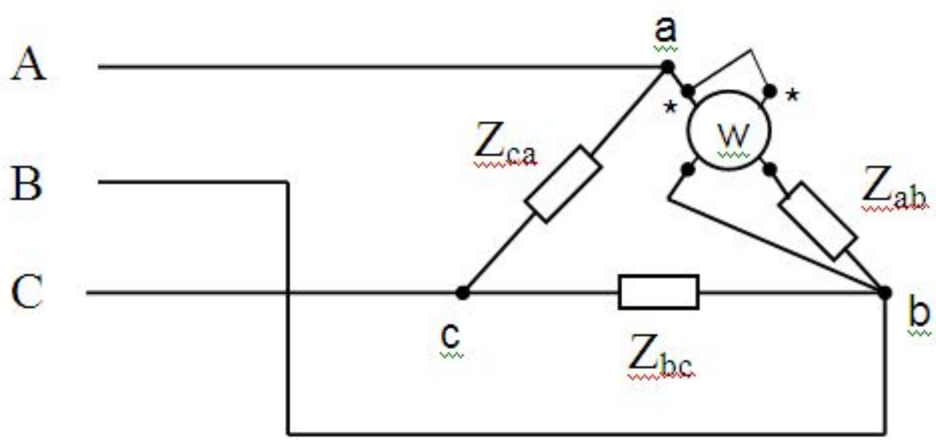
At four-wire asymmetric load

1. Way of one wattmeter.
At symmetric loading.



$P_w = I_a U_a \cos(\dot{I}a, \wedge \dot{U}_a)$

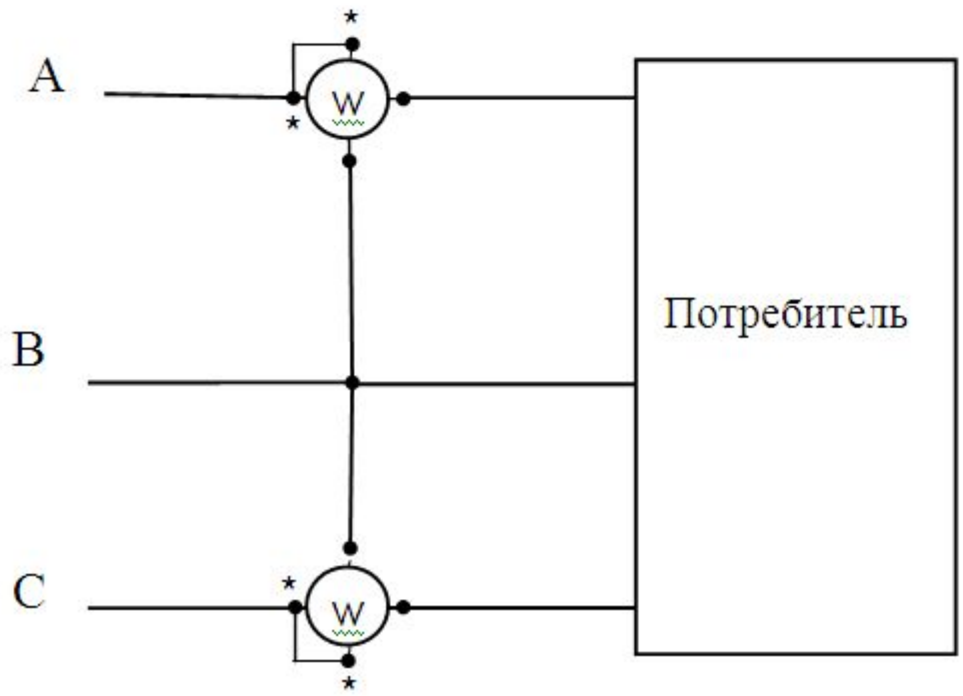
$P = 3P_w$



$P_w = I_{ab} U_{ab} \cos(\dot{I}_{ab}, \wedge \dot{U}_{ab})$

$P = 3P_w$

2. Way of two wattmeters.
At three-wire non-symmetrical load

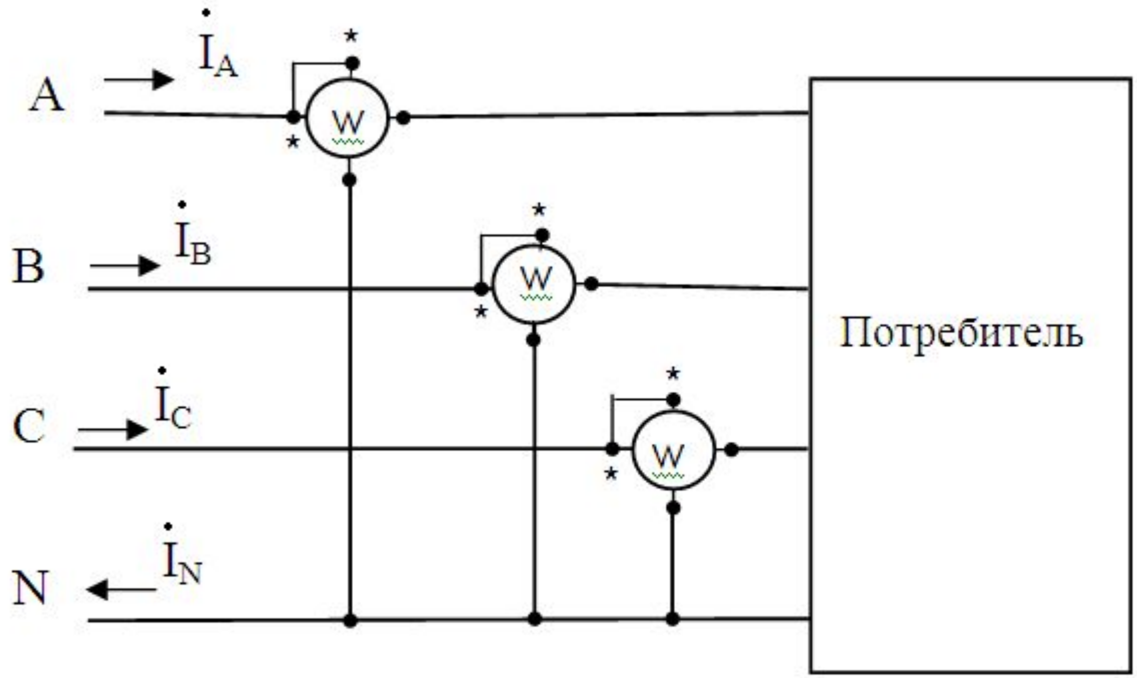


$$P = P_{w1} + P_{w2}$$

$$P_{w1} = I_A U_{AB} \cos(\dot{I}_A, \hat{}\,\dot{U}_{AB})$$

$$P_{w2} = I_C U_{CB} \cos(\dot{I}_C, \hat{}\,\dot{U}_{CB})$$

3. Way of three wattmeters.
At four-wire asymmetric load



$P = P_{w1} + P_{w2} + P_{w3}$

$P_{w1} = I_A U_A \cos(\dot{I}_A, \hat{} \dot{U}_A)$

$P_{w2} = I_B U_B \cos(\dot{I}_B, \hat{} \dot{U}_B)$

$P_{w3} = I_C U_C \cos(\dot{I}_C, \hat{} \dot{U}_C)$

Questions for self-preparation:

1. Connection of load phases by triangle.
2. Simmetichny loading
3. Asymmetrical loading
4. Power of three-phase electrical circuit.
5. Measurement of active power

Учебно-методические материалы по дисциплине

1. Герасимов В. Г. Электротехника. - М.: Высшая школа, 1985. -161с.
2. Борисов Ю. М. Электротехника. -М.: Энергоатомиздат, 1985. -185с.
3. Касаткин А. С., Немцов М. В. Электротехника. –Л.: Энергоатомиздат, 1983. -120с.
4. Волынский В. Г. Электротехника. -М.: Высшая школа, 1985. -299с.
5. Пантюшин В. С. Электротехника. - М.: Высшая школа, 1976. -25с.
6. Иванов И. И. Электротехника. - М.: Высшая школа, 1984. -20с.
7. Иванов А. А. Электротехника. Лабораторные работы. - Киев: Высшая школа, 1982. -50с.
8. Рекус Г. Г. Электротехника и основы электроники. - М.: Высшая школа, 1984. -50с.