Ministry of Education and Science of Russian Federation

Federal State Autonomous Educational Institution of Higher l Education

Tomsk Polytechnic University

Institute of Power Engineering

Electrotechnical Complexes and Materials Department

REPORT

Laboratory session 1
TESTING OF THREE PHASE TRANSFORMER UNDER SYMMETRICAL LOAD

Student - ________________________, group - _____________________,

I certify that my answers here are my own work, and that I have appropriately acknowledged all external sources (if any) that were used in this work.

Signature ________________________, date ____________________________.

Consultant - ________________________, position - ______________________,

Signature ________________________, date ______________________________.

Tomsk – 2014

Purpose of laboratory session

The purpose of the given work is to carry out tests under open circuit and short circuit modes of the transformer and obtain parameters of equivalent circuits under different modes.

Operating program

1. To examine the working principle of the transformer and to classify the types of transformers.
2. To define the laboratory unit.
3. To make an experiment of open circuit mode of the transformer and to build open circuit mode characteristics.
4. To calculate parameters of the transformer equivalent circuit under open circuit mode.
5. To provide test of short circuit mode of the transformer and to build short circuit mode characteristics.
6. To calculate parameters of the transformer equivalent circuit under short circuit mode.
7. To analyze the transformer characteristics under open circuit and short circuit modes and make conclusions.

Self-instruction

Power transformer – *(give the definition)*___________________________________

____

____

____

____

The transformer consists of following main components:

1.____

2.____

3.____

The working principle of the transformer is based on _________________________

____

____

____

The equivalent circuit of the transformer is the combination three circuits:

1.____

2.____

3.____

The three windings on either side of a three-phase transformer can be connected either in:

1.____

2.____

3.____

The three phase transformer windings can be connected in ___________________ vector groups and the most common used are_________________________________.

The voltage equations of primary and secondary windings:

______=____,

______=____,

where ______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

______ - ____,

The referring of the secondary winding values to the primary side:

$\dot{E}'_s =$ ____,

$\dot{I}'_s =$ ____,

$r'_s =$ ____,

$x'_{\sigma s} =$____,

The purpose of referring of the secondary winding to the primary side is ________

____

____

Draw the equivalent circuit of the transformer referred to the primary and make all necessary notes.

Fig. 1. Equivalent circuit of the transformer referred to the primary

Fig. 1. Notes ____

____

____

The ways for equivalent circuit parameters determination could be divided:

1.____

2.____

The equivalent circuit of the transformer allows studying of ____

The open circuit mode of the transformer is ____

The open circuit test of the transformer is performed when____

The turns ratio of the transformer____

To open circuit losses could be included following ____

Open circuit characteristics are following ____

The short circuit mode of the transformer is ____

The difference between short circuit test and real short circuit mode____

The rated short circuit voltage is ____

To short circuit losses could be included following ____________________________

____

____

Short circuit characteristics are following ______________________________

____

____

Draw the energy flow diagram of the transformer and make all necessary notes.

Fig. 2. Energy flow diagram of the transformer

Fig. 2. Notes ____

____

____

____

____

The efficiency of the transformer is ________________________________

____

____

______

$\eta =$ ____________________________________,

where ______= ____,

______ - ____,

______ - ____,

______ - ____,

______= ____,

______ - ____,

______ - ____,

______ - ____.

Therefore η = ________________________________.

Testing of the transformer

Before turning the module ON: a) double-check your wiring, wiring connection should be examined by consultant also; b) make sure that the voltage adjustment knob is in the "zero" position.

Note that wattmeter, amperemeter, voltmeter have different scales for open circuit (XX) and short circuit (КЗ) modes.

Caution! When actual equipment is used, high voltages may be present. NEVER make or modify any connection with the power ON unless otherwise instructed.

Open circuit test

Before turning the module ON make sure that knob XX-КЗ (open circuit – short circuit) is in XX position.

In fig. 3 and 4 the physical arrangement and the equivalent circuit of open circuit mode are presented.

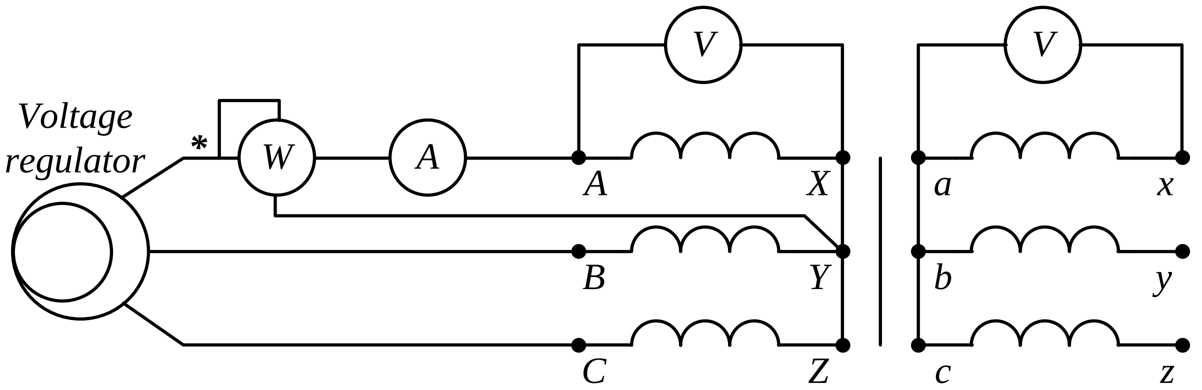

Fig. 3. Physical arrangement

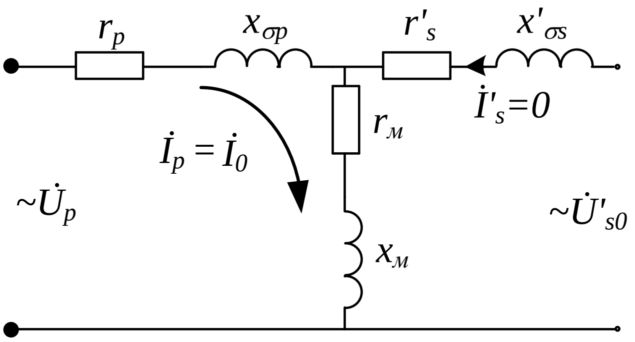

Fig. 4. Equivalent circuit of no-load mode of the transformer

The experiment is provided for primary voltage values $U_p = (0{,}2 \ldots 1.2)U_{prated}$.

Table 1.

<table>
<tr><td rowspan="3"></td><td colspan="4">Experiment</td><td colspan="3">Calculation</td></tr>
<tr><td>U_p</td><td>U_{so}</td><td>I_{p0}</td><td>P_{p0}</td><td>P_0</td><td>$\cos\varphi_0$</td><td rowspan="8">k =________________;
$I_{p0rated}$=____________, A;
$i_{o\%}$=________________, %;
P_{0rated}=____________,W;
$cos\varphi_{0rated}$=_________.</td></tr>
<tr><td>V</td><td>V</td><td>A</td><td>W</td><td>W</td><td>-</td></tr>
<tr><td>1.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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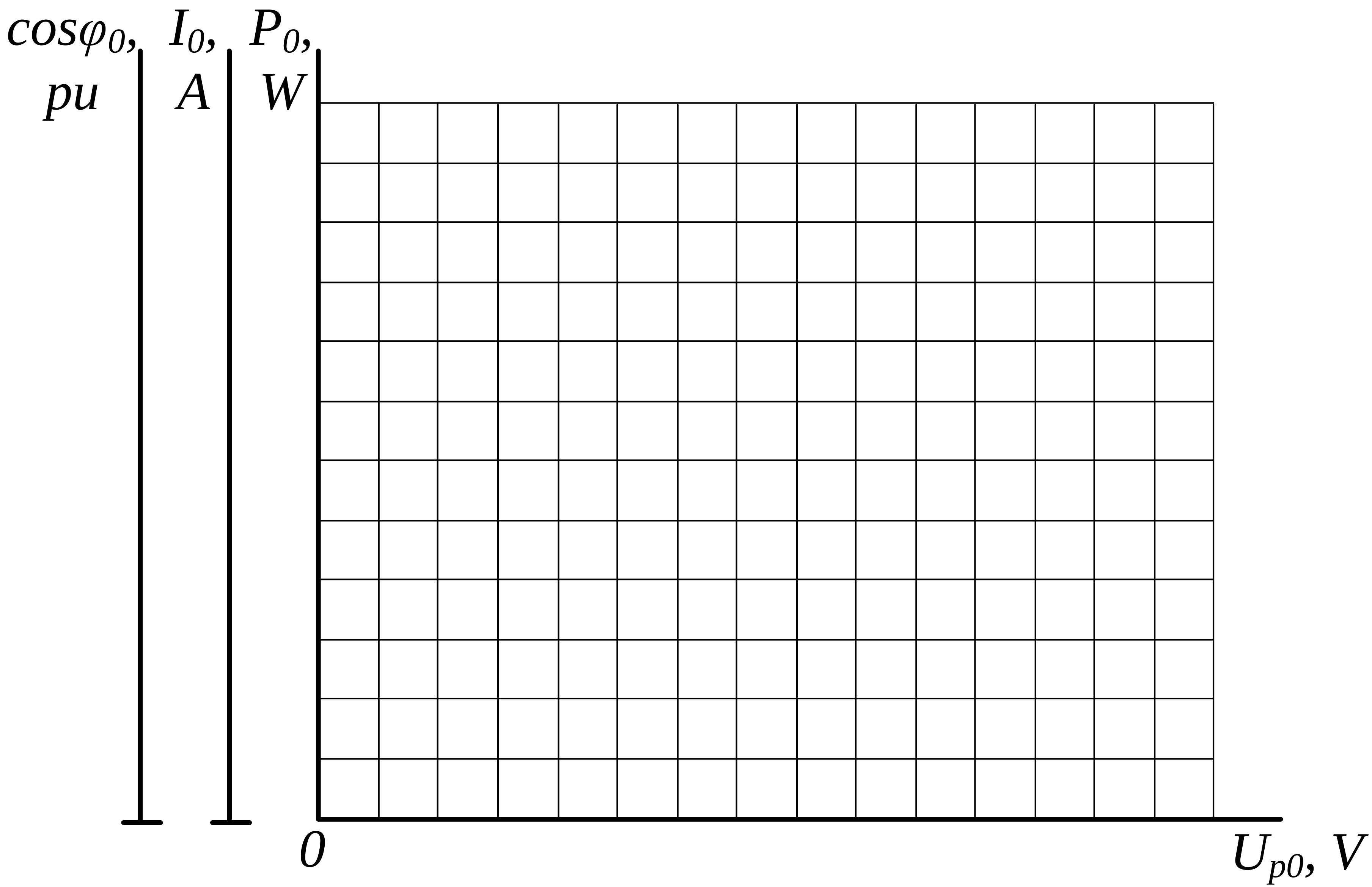

Fig. 5. Open circuit characteristics of the transformer

The example of calculations should be provided for one point $U_p = U_{prated}$.

Consumed power of three phase transformer is:

$$\mathrm{P}_0 = 3 \cdot \mathrm{P}_{\mathrm{p}0} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \mathrm{W},$$

where $\mathrm{P}_{\mathrm{p}0}$ – active power of the transformer per one phase.

The turns ratio is:

$$k = \frac{U_p}{U_{so}} = \frac{\qquad\qquad}{\qquad\qquad} = \_\_\_\_\_\_\_\_\_\_\_\_.$$

where U_p –voltage of primary winding, U_{so} – voltage of secondary winding while rated value at the primary side.

Power factor during open circuit mode:

$$cos\varphi_0 = \frac{\mathrm{P}_{\mathrm{p}0}}{U_p \cdot I_{p0}} = \frac{\qquad\qquad}{\qquad\qquad} = \_\_\_\_\_\_\_\_\_\_\_\_.$$

where I_{p0} – current of primary winding during open circuit mode.

Rated values of current $I_{p0_{rated}}$, power $\mathrm{P}_{\mathrm{p0rated}}$ and power factor $cos\varphi_{0_{rated}}$ of primary winding at open circuit mode are determined at the rated value of primary voltage supplied to the terminals U_{prated}, this values are found on open circuit characteristics.

Rated current of open circuit mode:

$$i_{o\%} = \frac{I_{p0_{rated}}}{I_{prated}} \cdot 100\%,$$

where $\mathrm{I}_{\mathrm{prated}}$ – rated current of primary winding.

Equivalent circuit during open circuit have following parameters (fig. 4): r_p – resistance of the primary winding, $\mathrm{x}_{\sigma\mathrm{p}}$ - leakage inductance reactance of primary winding, r_m and x_m - resistance and inductance reactance of the excitation circuit. The parameters of equivalent circuit of the transformer are calculated on the basis of rated values of open circuit and short circuit tests of the transformer.

As $U_p = U_{prated}$ following values could be determined:

$$Z_1 + Z_\text{м} = \frac{U_p}{I_{p0_{rated}}}, \quad r_1 + \mathrm{r}_\mathrm{m} = \frac{\mathrm{P}_{\mathrm{p0rated}}}{3 \cdot \left(I_{p0_{rated}}\right)^2},$$

as $Z_1 \ll Z_\text{м}$ and $r_1 \ll \mathrm{r}_\mathrm{m}$ thus

$$Z_\text{м} = \frac{U_p}{I_{p0_{rated}}} = \frac{\qquad\qquad}{\qquad\qquad} = \_\_\_\_\_\_\_\_\_\_ \Omega,$$

$$\mathrm{r}_\mathrm{m} = \frac{\mathrm{P}_{\mathrm{p0rated}}}{3 \cdot \left(I_{p0_{rated}}\right)^2} = \frac{\qquad\qquad}{\qquad\qquad} = \_\_\_\_\_\_\_\_\_\_ \Omega,$$

$$x_\mathrm{m} = \sqrt{{Z_\text{м}}^2 - {\mathrm{r}_\mathrm{m}}^2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \Omega.$$

Short circuit test

Before turning the module ON make sure that knob XX-К3 (open circuit – short circuit) is in К3 position, as in this position to the primaries will supplied the smaller value of voltage, otherwise there will be fault mode.

In fig. 6 and 7 the physical arrangement and equivalent circuit of short circuit mode are presented. The experiment is provided with such smaller values of supplied primary voltage that currents in primary and secondary windings do not exceed rated values.

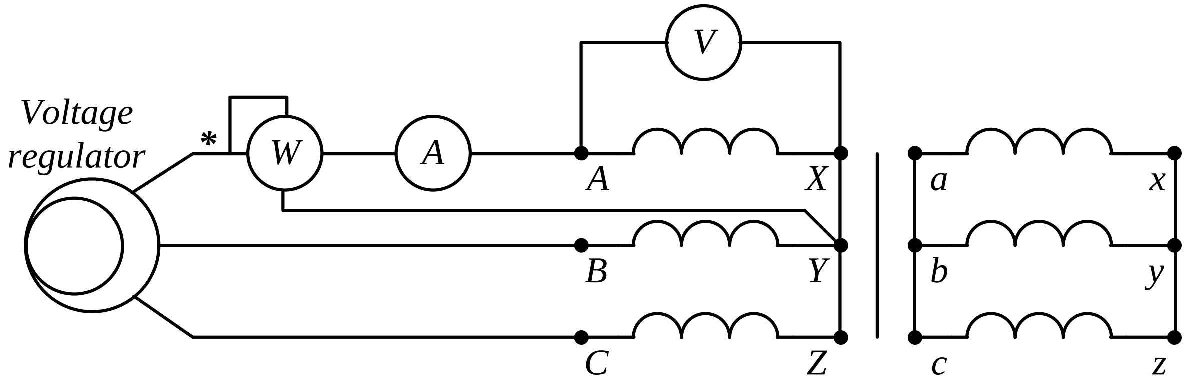

Fig. 6. Physical arrangement

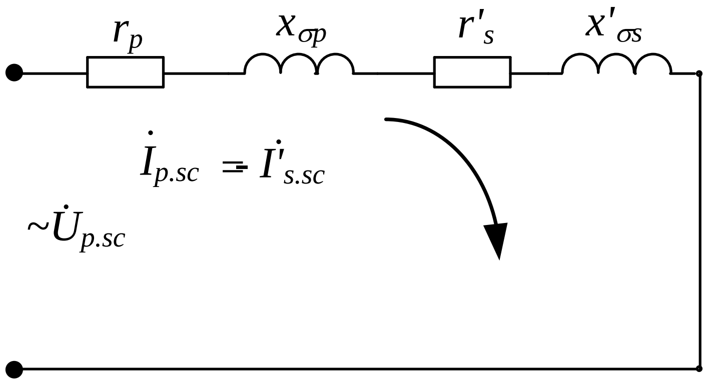

Fig. 7. Equivalent circuit of short circuit mode of the transformer

Table 2.

	Experiment			Calculation		
	$U_{p.sc}$	$I_{p.sc}$	$P_{p.sc}$	P_{sc}	$\cos\varphi_{sc}$	
	V	A	W	W	-	$u_{sc\%}$=_______________, %; $P_{sc.rated}$=____________,W; $\cos\varphi_{sc.rated}$=________.
1.						
2.						
3.						
4.						
5.						
6.						

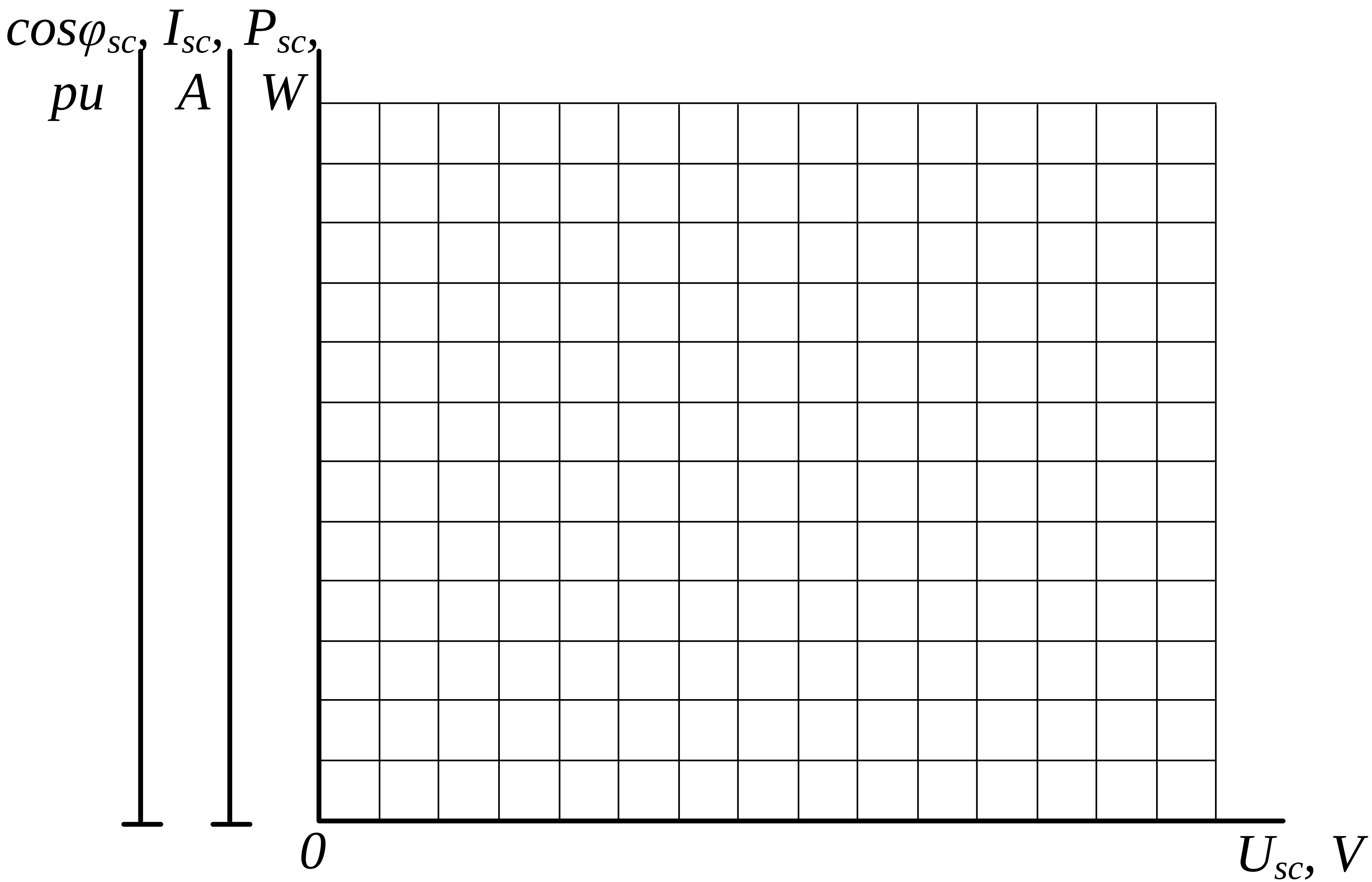

Fig. 8. Short circuit characteristics of the transformer

The example of calculations should be provided for one point $I_p = I_{prated}$.

Consumed power of three phase transformer is:

$$P_{sc} = 3 \cdot P_{p.sc} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ W,$$

where $P_{p.sc}$ – active power of the transformer per one phase under short circuit mode.

Power factor during open circuit mode:

$$cos\varphi_{sc} = \frac{P_{p.sc}}{U_{p.sc} \cdot I_{p.sc}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_.$$

where $I_{p.sc}$ – current of primary winding during short circuit mode.

Rated values of power $P_{sc.rated}$, voltage $U_{p.sc.rated}$ and power factor $cos\varphi_{sc.rated}$ of primary winding at open circuit mode are determined at the rated value of primary current I_{prated}, this values are found on short circuit characteristics.

Rated value of short circuit voltage:

$$u_{sc\%} = \frac{U_{p.sc.rated}}{U_{p.rated}} \cdot 100\%,$$

where $U_{p.rated}$ – rated voltage of primary winding.

Equivalent circuit during open circuit have following parameters (fig. 7): r_{sc} and x_{sc} – resistance and reactance of summative impedance, Z_{sc} – impedance of transformer under short circuit mode.

$$Z_{sc} = \frac{U_{p.sc.rated}}{I_{p.rated}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \Omega,$$

$$r_{sc} = \frac{P_{sc.rated}}{3 \cdot \left(I_{p.rated}\right)^2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \Omega,$$

$$x_{sc} = \sqrt{{Z_{sc}}^2 - {r_{sc}}^2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \Omega.$$

Approximately the following expressions could be written:

$$Z_p = Z'_s = \frac{Z_{sc}}{2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \Omega,$$

$$r_p = r'_s = \frac{r_{sc}}{2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \Omega,$$

$$x_{\sigma p} = x'_{\sigma s} = \frac{x_{sc}}{2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_ \Omega,$$

where Z_p – impedance of primary winding, Z'_s – impedance of secondary winding referred to primary side, Z_{sc} – impedance of transformer under short circuit mode, r_p - resistance of primary winding, r'_s – resistance of secondary winding referred to primary side, r_{sc} –resistance of transformer under short circuit mode, $x_{\sigma p}$ - leakage inductance reactance of primary winding, x'_s – leakage inductance reactance of secondary winding referred to primary side, x_{sc} – leakage inductance reactance of the transformer under short circuit mode,.

Conclusion

References

1.

2.

3.