

PROGRAM FOR THE CALCULATION OF POWER TRANSFORMER

N. T. RUSTAMOV

Doctor of Technical Sciences, professor of International Kazakh –
Turkish University named after Khoja Ahmed Yasawi

A. B. BEKBOLATOV

Master student at the International Kazakh –
Turkish University named after Khoja Ahmed Yasawi

Introduction

There are many programs are used to calculate power transformers in enterprises. They are used by a narrow circle of specialists and their intellectual property. For the reason, these programs are not available to use by a wide range of other engineers and professionals.

Therefore purpose of the article is to make model program in order to calculate power transformers, which can be accessibly applied by whole professionals in this field.

Elaboration of program

Structure for the calculation of program will be designed in next consequences [1]:

1. Definition of basic electrical value:
 - 1.1. Definition of line and phase meaning of electric current and voltage in windings LV and HV;
 - 1.2. Definition of test voltages in windings;

2. Selection of transformer type and its main component parts; magnetic circuit, windings, tank, voltage regulator, cooling type:

2.1. Tentative calculation of basic dimensions in the magnetic circuit:

- choose the brand and thickness of the transformer sheet and its isolation;
- choose induction in the core and yoke;
- determine the number of steps and the diameter of the core;
- define the size of basic insulation distances in the windings;
- determine the estimated size of the magnetic circuit;

2.2. Calculation of LV and HV windings:

- selection of LV and HV windings types;
- calculation of sheets quantity, thereafter the size of LV and HV windings;

2.3. Selecting the type of tanks and determining their size;

2.4. Selecting the type of voltage regulator;

2.5. Selecting the type of cooling;

3. Determination of electrical parameters and mechanical strength of windings:

3.1. Definition of basic and additional losses in the copper windings and loss of the short-circuit;

3.2. Determination of the short-circuit voltage;

3.3. Determination of mechanical forces in the windings in the short circuit;

4. Determination of mechanical forces in the windings in the short circuit:

4.1. Determination of the steps and active section of the core and yoke, plan maps of magnetic sheets;

4.2. Determination of weight of the magnetic circuit;

4.3. Determination of no-load losses;

4.4. Determination of current at no-load losses;

5. Thermal design of the active part:

- 5.1. Determination of overheat of windings compared to oil temperature;
- 5.2. Determination of overheat of the core compared to oil temperature;
- 6. Calculation of the cooling systems:
 - 6.1. Determining the size of the tank;
 - 6.2. Determining the surface of cooling;
 - 6.3. Final calculation of the windings overheat and oil related to air temperature;
 - 6.4. Determination of weight of oil and basic dimensions of expander;
- 7. Design and layout of the transformer and mechanical calculation:
 - Magnetic circuit;
 - Fixing the windings;
 - Tank and auxiliary parts;

Approximate program for the calculation of power oil transformer [2]

1. Source database for the calculation :
 - nominal power S ;
 - the number of phases m ;
 - frequency $f=50$ F;
 - voltage U ;
 - combination of windings and group of their combination;
 - short-circuit voltage u_{sh} ;
 - no-load losses P_0 ;
 - short-circuit losses P_{sh} losses;
 - mode work – normal;
 - method of cooling – oil with natural termosiphon circulation;
 - installation – external;

Determination of the base electrical values

The first step of the program is to determine sum of power, which is calculated as sum of power consumed by each winding:

$$P_{\text{sum}} = U_1 I_1 + U_2 I_2 + \dots + U_n I_n \quad (1)$$

where: $U_1 I_1$, $U_2 I_2$ and etc. – production of voltages and currents in the secondary windings

The second step of the program is to define overall power:

$$P_1 = \frac{P_{\text{sum}}}{\text{COE}} \quad (2)$$

COE can be defined from table 1:

Determination of efficiency coefficient

Table 1

Sum power, B τ	10-20	20-40	40-100	100-300
COE of transformer	0,8	0,85	0,88	0,92

The third step of the program is to determine the cross-section **S** of the working core:

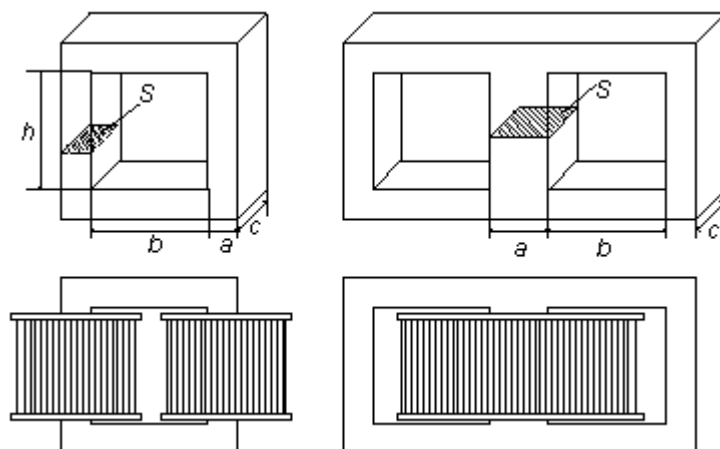
$$S = 1,2 \cdot \sqrt{P_1} \quad (3)$$

where the cross-section is in

The fourth step of the program is to work out the width **a** of the working core:

$$a = 0,8 \cdot \sqrt{S} \quad (4)$$

The fifth step of the program is to choose the form of the core. Of receipt value **a**(cm) we are going to choose next value from the available cores:



Picture 1. Forms of the transformer core and disposition windings in it

The sixth step of the program is to determine the thickness of the package c :

$$c \frac{S}{a} \quad (5)$$

The seventh step of the program is to find the number n of coils per 1 volt:

$$n \frac{k}{S} \quad (6)$$

The coefficient k is usually in the range of $35 \div 60$. It depends on the properties of plates in the core steel [4].

Steel thickness with 0,35 mm:

- for cores such as C - shaped pattern with thin steel $k = 35$;
- for cores like O – shaped pattern assembled from Π or Γ – shaped pattern plates without holes by corner $k = 40$;
- for plate type such as III – shape pattern without holes $k = 45$;
- for plate type as III – shaped pattern with holes $k = 50$;
- for plate type like III – shaped pattern with holes and thickness 0,35 mm $k = 60$;

The eighth step of the program is to determine the number **n** of coils in the primary winding:

$$W = U \cdot n \quad (7)$$

The ninth step of the program is to determine the number of coils in the secondary winding and there is necessity in including an additional coefficient **m** which takes a drop of voltage into account in it:

$$W = m \cdot U \cdot n \quad (8)$$

Dependence the coefficient m from the current which flows through the winding

Table 2

Strength of the secondary winding, A	0,2-0,5	0,5-1,0	1,0-2,0	2,0-4,0
m	1,02	1,03	1,04	1,06

The tenth step of the program is to determine diameter **d** of the conductor of the secondary windings:

$$d = p \cdot \sqrt{I} \quad (9)$$

where: **d** – diameter of copper conductor, mm;

I – current force in the winding, A;

p – coefficient which takes available heat into account depending on brand of conductor

Determination of the coefficient p in dependence on brand of current

Table 3

Brand of current	PEL	PEV-1	PEV-2	PET
p	0,8	0,72	0,69	0,65

The eleventh step of the program is to determine current **I** in the primary winding:

$$I = \frac{P_i}{U} \quad (10)$$

An example to step calculation of power transformer:

Represented table below gives dates for secondary winding

Table 4

Winding	Number of cols, W	Diameter of copper current, d, mm	Diameter of current in isolation, mm
I (primary)	1680	0,24	0,25
1	50	0,9	0,99
2	94	0,41	0,45
3	917	0,18	0,2

An example for the calculation:

It is necessity to calculate with following dates:

$$U_1 = 6,3 \text{ B}$$

$$I_1 = 1,5 \text{ A}$$

$$U_2 = 12 \text{ B}$$

$$I_2 = 0,3 \text{ A}$$

$$U_3 = 120 \text{ B}$$

$$I_3 = 0,059 \text{ A}$$

Find summary power:

$$P_{\text{сум}} = U_1 I_1 + U_2 I_2 + \dots + U_n I_n = 6,3 \cdot 1,5 + 12 \cdot 0,3 + 120 \cdot 0,059 = 20,13 \text{ BТ}$$

Using Table 1 we shall define an overall capacity P_1 :

$$P_i = \frac{P_{\text{sum}}}{\text{COE}} = \frac{20,13}{0,85} = 23,7 \text{ BТ}$$

To find the cross-section **S** of the core:

$$S = 1,2 \cdot \sqrt{P_1} = 1,2 \cdot \sqrt{23,7} = 5,84 \text{ cm}^2$$

To find approximate meaning of the width **a**:

$$a = 1,8 \cdot \sqrt{S} = 0,8 \cdot \sqrt{5,84} = 1,94 \text{ cm}$$

By choosing the plate type for transformer III – 19, for which $a = 1,9$ cm, we shall find the thickness **c** of the package:

$$c = \frac{S}{a} = \frac{5,84}{1,9} = 3,1 \text{ cm}$$

Through received cross-section of the working core there is **S**:

$$S = a \cdot c = 1,9 \cdot 3,1 = 5,89 \text{ cm}^2$$

To determine coefficient **k**. If there is used the plate of transformer sheet with type such as III – 19 without holes with corner, then $k = 45$. To define number **n** of coils per 1B:

$$n = \frac{k}{S} = \frac{45}{5,89} = 7,64$$

To define number of coils in the primary winding on condition of net is voltage 220B

$$W_1 = U_1 \cdot n = 220 \cdot 7,64 = 1680 \text{ ВИТКОВ}$$

To define coefficient **m** from table 3 for secondary winding:

$$\text{if } I_1 = 1,5 \text{ A} \quad m_1 = 1,04$$

$$\text{if } I_2 = 0,3 \text{ A} \quad m_2 = 1,02$$

$$\text{if } I_3 = 0,059 \text{ A} \quad m_3 = 1$$

To find number of coils from every secondary winding until earlier entire number:

$$W_1 = m_1 \cdot U_1 \cdot n_1 = 1,04 \cdot 6,3 \cdot 7,64 = 50 \text{ coils}$$

$$W_2 = m_2 \cdot U_2 \cdot n_2 = 1,02 \cdot 12 \cdot 7,64 = 94 \text{ coils}$$

$$W_3 = m_3 \cdot U_3 \cdot n_3 = 1 \cdot 120 \cdot 7,64 = 917 \text{ coils}$$

To define current force in the primary winding:

$$I_1 = \frac{P_i}{U_{\text{сети}}} = \frac{23,7}{220} = 1.108 \text{ A}$$

To define diameter of conductor of primary winding:

$$d_1 = p \cdot \sqrt{I_1} = 0.72 \cdot \sqrt{1.108} = 0.236 \text{ мм}$$

Accordingly, we are realizing a step illustration of the calculation for transformer.

Calculation of transformer is implemented in program language C++ [3].

Structure of program is led to Listing – Supplement № 1.

Conclusions:

1. Represented structure of the calculation for transformer.
2. Realized a step illustration of the calculation for base electrical values of transformer.
3. On program language C++ represented concrete illustration of the calculation for transformer.

References

1. Transformers – The Basics. Martin Grech, Geoff Severt, Copyright 2001
2. Leslie Lamport "Predicate Transformers for Concurrency". ACM Transactions on Programming Languages and Systems 2009.
3. Бондаренко С. В. Бондаренко М. Ю. Программирование на языке C++ в MVS. 2010.
4. Antonov, D., Ovcharov, P. Determination of internal stress in welding apparatus subjected to mechanical and thermal stress. // XX Scientific and technical international conference Defektoskopiya'2005 "2005.