BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Volumul 70 (74), Numărul 1, 2024
Secţia
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ
DOI:10.2478/bipie-2024-0002

PERFORMANCE IMPROVEMENT OF DISTRIBUTION TRANSFORMERS FOR THE ENERGY SYSTEM

BY

VERONICA-CARMEN GHEORGHE* **and RADU BURLICĂ**

“Gheorghe Asachi” Technical University of Iași,
Faculty of Engineering Electrical, Energy and Applied Informatics, Iași, Romania

Received: June 13, 2024
Accepted for publication: April 1, 2025

Abstract. Rapid advances and developments in the design, modernization, and optimization of transformers have generated an increase in power for the lines of distribution, with transformers occupying important positions in the national and international power systems.

This paper compares both the output parameters generated by the design process, the values obtained between 400 kVA transformers, a distribution transformer with conservative, and a hermetic transformer with air cushion (EPA). We use the same construction of the transformer core with columns and yokes made of a sheet of steel with angle-cut unoriented crystals and for the coils, use the copper conductor insulated with paper. The overall dimensions, the total mass of the transformers, the heating calculation, and their efficiency are compared.

It has proven that all materials used in the manufacture of a distribution transformer must have superior properties. Using the newest materials in the field we increase the performance of distribution transformers.

Keywords: Power, losses, conductors, coils, core.

---

*Corresponding author; *e-mail*: veronica-carmen.gheorghe@student.tuiasi.ro

1. Introduction

At present are use the transformers three phases, with oil conservative, mineral oil-immersed, natural air-cooled ONAN, suitable for outdoor installation and designed, constructed, and tested according to the follows of International Standards IEC: 76; 296; 354; 551. The transformers operate satisfactorily under variations of load, voltage short circuits, or other conditions that may occur. Transformers are capable of withstanding without breaking down, all types of short circuits on the terminals, according to IEC 76-5. Transformers have a well-defined functional role, they are used to carry out in good conditions all the processes related to production, modification of the parameters value, transport, distribution, and use of electrical energy.

The heating of transformers in operations is a consequence of energy losses through the Joule-Lenz effect, eddy currents, hysteresis losses, the magnetization of parts made of ferromagnetic materials, and losses in dielectrics located in electric fields (Eslamian *et al*., 2021).

When designing distribution transformers, these phenomena are considered, because the control of the heating level during operation at normal parameters guarantees a long operation time. The longer the operating time, the better the quality of the transformers. The design of hermetically sealed transformers resulted in the reduction of the main dimensions and the quantity of materials used in their manufacture (Kulkarni and Khaparde, 2004).

In a transformer immersed in oil, the edge failures increase the current, which is followed by increasing the temperature inside the transformer. The temperature increase affects the properties of oil and the portions of the paper, reducing the performance of the transformer. The steel sheets of the core with defects a marginal and insulation degradation affect the transformer core. These defects are more significant as the flux density and the number of steel sheet laminations in the short circuit increase, and a large current loss develops in the transformer core. These can cause flow distortions in the cruciform stacked cores and high localized heating inside and outside the affected region. Manufacturers of rolled steel sheets for transformers should be aware of and consider the serious repercussions due to the marginal faults in the steel sheet laminates and take the necessary precautionary measures to eliminate them (Altayef *et al*., 2022).

The hybrid distribution transformer has better controllability for system currents and voltages. To reduce the number of discrete magnetics and make highly efficient use of ferromagnetic materials was proposed a novel structure of HDT with magnetic integration. The hybrid distribution transformer is a novel controllable transformer, and they are helpful for future design and optimization (Liu *et al*., 2021).

An integrated transformer design methodology for dual-active-bridge DAB converters, which utilizes leakage inductance, to substitute a cumbersome inductor in the conventional DAB converters. The proposed integrated transformer with integrated leakage inductance inherently includes leakage inductance and magnetizing inductance, whose values can be appropriately selected by modulating the number of turns and the center-core air gap (Li *et al*., 2012).

Based on the theoretical analysis of the DAB converters, the major parameters, primary and secondary current levels, and their phase difference, can be derived, and these values are utilized for magnetic analysis of the proposed integrated transformer (Lee *et al*., 2021). An integrated transformer design methodology applied to DAB converters provides a low transformer loss for the high-efficiency operation of the proposed integrated transformer (Zhao *et al*., 2022).

2. Establishing the Main Dimensions of the Transformer

In developing the energy system, the efficient construction of transformers is primarily used in optimizing them. Rapid changes and developments are in transformer design, analysis, manufacturing, and monitoring technologies. There is a continuing trend to opt for higher system voltages for transmission, increasing transformers' voltage rating. In the preliminary calculation of a transformer, the problem arises of establishing indicative values for the main dimensions based on the initial data:

– Nominal apparent power
– Primary and secondary line voltage
– Working frequency
– Number of phases of transformer
– The Connection Group
– Working regime: long, short-term, intermediate
– Constructive types: in oil

Table 1
The parts of the distribution transformers with oil conservatoire

General parts	Standard accessories	Accessories on request
Steel core *Wraps* *Switch* *Cross insulators* *Jet* *The lid of the tub* *Roller* *Conservative* *Buchholz relay*	*Oil level indicator* *Thermometer housing* *Safety valve* *Plotter switch* *Ears lifting* *Label with date* *Ground terminals* *Two-way wheels* *H.V., L.V., insulators*	*Thermometer with 2 contacts* *Silica gel filter* *Buchholz relay Protection device DGPT2 (Paithankar, 2017)* *Auxiliary terminal boxes* *Overpressure valve* *H.V., L.V., terminal protection box*

Table 1 presents the general parts of the distribution transformers, the standard accessories, and the accessories requested by the beneficiaries of the transformers by the offer request.

Table 2
Additional data that must be observed

Parameters	Possible variation [%]
Power absorbed P_0	*+20*
Power absorbed in short circuit P_k	*+10*
Relative short circuit voltage u_k	*± 10 error*
Relative no-load current	*up to +30*

Table 2 presents the values in percentages that must be added to the data obtained from the design calculations of the transformer.

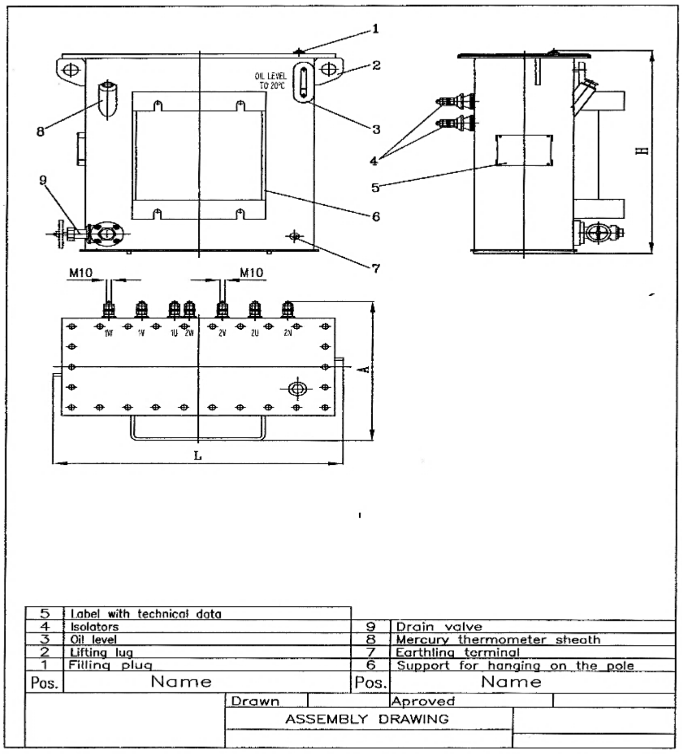

Fig. 1 – Ensemble drawing for transformer type TTU-EPA.

In Fig. 1 are present the ensemble drawings of the hermetic transformer with air cushion type TTU-EPA (Gheorghe and Roșu, 2009).

The magnetic core is made of sheet steel cold-rolled lamination, with silicon, of high quality with unoriented crystals, with low specific loss, coated with a material stable under the action of hot oil pressure. The columns of the core are stiffened with a special varnish, and the yokes are reinforced with a steel frame to reduce the air gap (Li *et al.*, 2012).

The core shall be internally grounded by grounding bonds.

The diameter D_m result is as follows: on each main column of a transformer there is a primary and secondary winding.
Voltage drops are neglected:

$$S_c = U_1 \cdot I_{1N} \cong E_1 \cdot I_{1N} \tag{1}$$

$$E_1 = \frac{2 \cdot \pi}{\sqrt{2}} \cdot f \cdot w_1 \cdot \Phi = \frac{2 \cdot \pi}{\sqrt{2}} \cdot f \cdot w_1 \cdot A_m \cdot B_m \tag{2}$$

$$\Phi = A_m \cdot B_m \tag{3}$$

$$A_m = k_m \cdot \frac{\pi \cdot D_m^2}{4} \tag{4}$$

$$k_m = k_\delta \cdot k_{Fe} \tag{5}$$

where: S_c – the apparent power that belongs to a main column

U_1 – the primary voltage, to the primary windings

I_{1N} – nominal current

E_1 – induced electromotive voltage

w_1 – the number of spires

A_m – useful cross-sectional area

B_m – maximum magnetic induction

k_m – the coefficient of iron filling of the circumscribed circle of the cross sections

k_δ – the ratio between the area occupied by steel sheets and the insulation between them and the area of the circle circumscribed by the cross sections of the column. It varies according to the number of steps of the cross-sections of the column and according to the tightening method

k_δ = 0.89÷0.92 for 4÷6 - steps and strengthening the column with the help of the winding cylinder L.V.

k_δ = 0.91÷0.93 for 6 ÷7 - steps and strengthening the column with bolts

k_{Fe} – is the ratio between the effective area of the sheets of steel and the area occupied by the sheets of steel, including the insulation between them

k_{Fe}= 0.85÷0.87, insulated with paper

k_{Fe} = 0.9÷0.93, insulated with varnish

k_{Fe} = 0.95÷0.98, for ceramic oxides

Winding is calculated, depending on the H.V., L.V., and P. Are assumed to be w_2 number of turns, after that result which the voltage e_2 in the L.V.

$$e_2 = \frac{Uf_2}{w_2} \tag{6}$$

Is calculated for f = 50 Hz:

$$B_c = \frac{e_2}{\pi \cdot \sqrt{2} \cdot c \cdot S_{Fe_c}} = \frac{e_2}{222.2 \cdot S_{Fe_c}} \tag{7}$$

For transformers in oil-immersed: $B_c = 1.3 \div 1.7$ [T]

$$B_y = \frac{S_c}{S_y} \cdot B_c \tag{8}$$

$$Z: U_f = \frac{2}{3} \cdot U_l \left(\frac{1.15}{\sqrt{3}} \cdot U_l\right) \tag{9}$$

$$\mathrm{S} = \sqrt{3} \cdot \mathrm{U_l} \cdot \mathrm{I_l} \tag{10}$$

$$I_l = \frac{S}{\sqrt{3} \cdot U_l} \tag{11}$$

$$Y: \ U_f = \frac{U_l}{\sqrt{3}} \tag{12}$$

$$I_f = I_l = \frac{S}{\sqrt{3} \cdot U_l} \tag{13}$$

$$\Delta: \ U_f = U_l \tag{14}$$

$$I_f = \frac{I_l}{\sqrt{3}} = \frac{P}{3 \cdot U_l} \tag{15}$$

$$I_{l_{1,2}} = \frac{P}{\sqrt{3} \cdot U_{1,2}} \tag{16}$$

$$w_1 = w_2 \cdot k_w \tag{17}$$

2.1. Calculation of the Magnetic Core in Steps

The magnetic circuit is made up of columns on which the windings of the transformers are placed and of the yokes, through which the magnetic flux of the columns is closed. Constructively, the shape of the columns and yoke sections are in steps. The number of steps and the dimensions of each step correlated with those of the yoke are standardized elements, as much as possible, for standardizing the manufacturing processes. As material for the magnetic cores of the transformers, cold-rolled silicon steel sheets are used, with unoriented crystals and low specific losses (depending on the type and quality of the sheet), with thicknesses of 0.27 ÷ 0.35 mm.

$$L_c = H - g \tag{18}$$

$$L_{1c} = L_c - B_c \tag{19}$$

$$L_c(m) = H - B_c \tag{20}$$

$$L_y(1) = F + B_c + g \tag{21}$$

$$L_{1y}(1) = L_y(1) - B_y \tag{22}$$

$$L_y(2) = F \tag{23}$$

$$L_{1y}(2) = L_y(2) - \frac{B_y}{2} \tag{24}$$

where: H – core height
H_f – window height
F – distance between the axes
L_f – window width
B_c – column width
B_y – the width of the yoke
L_c – the total length of the marginal column
L_c(m) – the total length of the middle column
L_y – the total length of the yoke

The net steel (transverse) section of the column is determined with the equation:

$$S_c = C_t \cdot \frac{S_1}{f} \qquad [\mathrm{m}^2] \tag{25}$$

where: S_c – column section, $[\mathrm{m}^2]$
S_1 – the apparent power of the transformer on a column, [VA]
f – supply voltage frequency, [Hz]
C_t – constant of calculation (4 ÷ 6)$\cdot 10^{-4}$

For the three-phase transformer with windings on three columns:

$$S_t = \frac{S_N}{3} \qquad [\mathrm{VA}] \tag{26}$$

The geometric dimensions of the column result from the values of the net sections of the column based on the following equation:

$$S_c = K_m \cdot \frac{\pi D \cdot c^2}{4} \tag{27}$$

$$D_c = \frac{4 \cdot Sc}{\pi K_m} \qquad [m] \tag{28}$$

2.2. Calculation of the Secondary Winding

Number of turns for the secondary winding:

$$w_2 = \frac{U_{2f}}{e} \quad (29)$$

$$e = 4.44 \cdot f \cdot S_c \cdot B_c \quad (30)$$

where: U_{2f} – the secondary phase voltage, [V]
e – electromotive voltage in a loop of conductor,[V/turn]

2.3. Calculation of the Primary Winding

Number of turns for the secondary winding:

$$w_1 = \frac{U_{1f}}{e} \quad (31)$$

where: U_{1f} – the primary phase voltage, [V]

Having the number of turns in the secondary and knowing the transformation ratio, w_1 can also be calculated with the equation:

$$w_1 = \frac{U_{1f}}{U_{2f}} \cdot w_2 \quad (32)$$

The number of turns is calculated as a percentage of w_1. The total number of turns on the primary winding will be w_1. The nominal transformation ratio must not exceed +5% of the guaranteed transformation ratio.

$$B_c = \frac{e}{4.44 \cdot f \cdot S_c S_c} \quad (33)$$

$$B_y = \frac{S_c}{S_y} \cdot B_c \quad (34)$$

where: B_c – magnetic induction in columns, [T]
B_y – magnetic induction in yoke, [T]
S_y – yoke section, [m^2].

2.4. The Section and Dimensions of the Copper Conductors

Rated currents of the transformers:

$$I_1 = \frac{S_n}{m \cdot U_{1f}} \quad (35)$$

$$I_2 = \frac{S_n}{m \cdot U_{2f}} \tag{36}$$

$$S_{w1} = \frac{I_1}{J_1}; \quad S_{w2} = \frac{I_2}{J_2} \tag{37}$$

where: I_1, I_2 – primary and secondary phase currents, in [A]
S_n – nominal power, in [kVA]
m – number of phases
J_1, J_2 – current densities must not exceed 3.3 in [A/ mm^2] for windings by copper conductors

2.5. Calculation of the Resistance of the Windings, Losses and the Total Weight of the Conductors

The resistance of the windings on the primary phase 1 and secondary phase 2, is calculated:

$$R_{1,2} = \frac{\rho_{t} \cdot w_{1,2} \cdot l_{med\ 1,2}}{S_{w1,2}} \tag{38}$$

$$l_{med\ 1,2} = \Pi \cdot D_{med\ 1,2} \tag{39}$$

where: ρ_t – resistivity of the winding, for the copper conductor, at temperature to work t, in [$\Omega \cdot \text{mm}^2 \cdot m^{-1}$]
ρ_{Cu75^0} = 0.0214, [$\Omega \cdot \text{mm}^2 \cdot m^{-1}$], for insulation class A (transformers in oil)
$l_{med\ 1,2}$ – the average length of the turn of the primary, and secondary winding, [m]
$S_{w1,2}$- the section of the conductors in the primary winding and in the secondary winding, [mm^2]

Losses windings are calculated with the equation:

$$P_{w_{1,2}} = m \cdot R_{1,2} \cdot I_{1,2} \quad [\text{W}] \tag{40}$$

where: $R_{1,2}$ – resistant primary, secondary windings, [Ω]
$I_{1,2}$– phase current of primary, secondary winding, [A]
m – number of phases

Total electrical losses or short-circuit losses at rated currents:

$$P_{k_N} = P_{w_1} + P_{w_2} \qquad [\text{W}] \tag{41}$$

The weight of the conductors in the primary 1 and secondary 2 windings:

$$G_{w_{1,2}} = \gamma_{1,2} \cdot S_{1,2} \cdot w_{1,2} \cdot l_{med.1,2} \quad [\text{kg}] \tag{42}$$

The net mass of the iron of all columns C, respectively, of all yokes J, for the three-phase transformer with three cones is:

$$G_{Fe_c} = 3 \cdot \gamma_{Fe} \cdot S_c \cdot L_c \quad [\text{kg}] \tag{43}$$

where: $\gamma_{Cu_{1,2}} = 8.9 \cdot 10^{-3}$, *the* specific mass of copper
γ_{Fe} =7.65$\cdot$ 10^{-3} [kg $\cdot$ cm^{-2}], specific mass of cast iron
L_c, L_y – the lengths of the columns, respectively the yoke, [cm^2]
S_c, S_y – the areas of the columns, respectively the yoke, [cm^2]

2.6. Calculation of the Short Circuit Voltages

$$u_K = Z_K \cdot \frac{I_{f1}}{U_{f1}} \cdot 100 \quad [\%] \tag{44}$$

$$Z_K = R_K^2 + X_K^2 \quad [\Omega] \tag{45}$$

$$R_K = K_w^2 \cdot R_2 + R_1 \quad [\Omega] \tag{46}$$

$$X_K = \frac{K \cdot \pi \cdot f \cdot D_{adverage} \cdot C \cdot w_1^2}{H_K} \tag{47}$$

$$D_{adverage} = \frac{D_{adverage\, w_1} + D_{adverage w_2}}{2} \quad [\text{cm}] \tag{48}$$

$$C = \frac{b_1 + b_2}{3} + a_{1,2} \quad [\text{cm}] \tag{49}$$

where: Z_K – short circuit impedance, [Ω]
I_{f1} – the phase current in the primary winding, [A]
R_K – short circuit resistance, [Ω]
F – nominal frequency, [Hz]
b_1 – the radial size of the primary coil
b_2 – the radial size of the secondary coil
$a_{1,2}$ – distance between the primary and secondary winding
w_1 – the nominal number of turns of the primary winding
H_K – primary winding height, [cm]

2.7. Calculation of Heating of the Transformer

In the radiator the temperatures inlet-outlet for oil, type ONAN – the temperature drop measured at the inlet and outlet: 14÷15°C.

$$S_{effective\ cover} = 0.75 \cdot L \cdot l \quad (50)$$

$$S_{effective\ radiator} = 0.85 \cdot P_{pipe} \cdot L_{pipe} \cdot N_{pipe} \quad (51)$$

$$S_{effective\ tank} = k \cdot S_{tank} \quad (52)$$

$$q_c = \frac{(P_0 + P_N) \cdot 1.1}{S_{total\ effective}} \quad (53)$$

where: 0.75 and 0.85 – coefficients of effectiveness
L_{pipe} – length pipe
N_{pipe} – number of pipes
For the elliptical pipe perimeter: $P_{pipe} = 0.161$ [m].
The surfaces of the collectors are also considered in the calculation of the number of radiators: k = 0.95, 0.85, 0.8.

Table 3
Calculation of the transformer TTO-ONAN 400 kVA – 20/0.4 kV/kV

H.V. Δ	L.V. Y_n
$U_f = U_l = 20000$ [V]	$U_f = \frac{400}{\sqrt{3}} = 230.94 \cong 231$ [V]
Connection: Δ	*Connection:* Y_n
$I_f = 6.67$ [A]	$I_f = 577.35 \cong 578$ [A]
Type of winding: Layered	*Type of winding: Cylinder in 2 layers*
$w_1 = \frac{U_{f1}}{U_{f2}} \cdot w_2$	$w_2 = \frac{U_{f2}}{e} = 20$ *no. turns*
$w_1 = 1732 \pm 87$ *no. turns*	$e = 222.2 \cdot S_{c2} \cdot B = 11.547 [V \cdot turn^{-1}]$
*Cu EMU*2∅1.35 *insulated* − 1.46	*Cu* 3.35 · 10.6 *insulated* − 0.44
$S_{c1} = 1.431$ [mm^2]	$S_{c2} = 4 \cdot 35 = 140$ [mm^2]
$J_1 = \frac{I_1}{S_1} = 4.66$ [$A \cdot mm^{-2}$]	$J_2 = \frac{I_2}{S_2} = 4.12$ [$A \cdot mm^{-2}$]
$H_1 = \pi \cdot d_{m1} = 3.14 \cdot D_{winding\ per\ col.}$	$H_2 = \pi \cdot d_{m2} = 3.14 \cdot D_{winding\ per\ col.}$

$H_1 = 0.975$ $[m]$ $L_{w_1} = \pi \cdot d_{m1} \cdot w_1 = 1691 \div 1776$ $q_{75^\circ} = 0.0214$ $[\Omega \cdot mm^2 \cdot m^{-1}]$ $R_{75^\circ} = \frac{\rho \cdot L_{w_1}}{S} = 25.29$ $[\Omega]$ $G_{1blank} = m \cdot L_{w_1} \cdot S_{c1} \cdot G_{Cu}$ $G_{1blank} = 68$ $[kg]$ $G_1 = 3 \cdot \gamma_{paper} \cdot L_{w_{1t}} \cdot S_{c1\,insulated}$ $G_{1insulated} = +2.5$ $[kg]$	$H_2 = 0.757$ $[m]$ $L_{w_2} = \pi \cdot d_{m2} \cdot w_2 = 16$ $[m]$ $q_{75^\circ} = 0.0214$ $[\Omega \cdot mm^2 \cdot m^{-1}]$ $R_{75^\circ} = \frac{\rho \cdot L_{w_1}}{S} = 0.00245$ $[\Omega]$ $G_{2blank} = m \cdot L_{w_2} \cdot S_{c2} \cdot G_{Cu}$ $G_{2blank} = 60$ $[kg]$ $G_2 = 3 \cdot \gamma_{paper} \cdot L_{w_{2t}} \cdot S_{c2\,insulated}$ $G_{2insulated} = +1.11$ $[kg]$
$H_1 = 247$ $[mm]$ *b = 24.5* $[mm]$	$H_2 = 250$ $[mm]$ *b = 20* $[mm]$
10 layers · 167 turns =1670 *1 layer · 149 turns = 149* *168 turns · 1.46 = 245.28* *11 layers · 1.46 = 16.06*	*11 ·2·11.04 = 242.88* *2 layers ·2 · 3.79=15.16* *Channel = 4* *Increase = 0.84*

Table 3 presents the calculation data sheet for a transformer type TTO-ONAN 400 kVA - 20/0.4 kV/kV (Gheorghe and Roșu, 2009).

Table 4

Transformer TTO-ONAN 400 kVA – 20/0.4 kV/kV

Type of connection	No load losses P_0 $[W]$	Load losses P_K $[W]$	Impedance voltage, at 75°C u_K [%]	Total weight for core $[kg]$
Dyn5	*917*	*6000*	*4*	*703*

Table 4 presents the data obtained in the design process of transformer type TTO-ONAN 400 kVA – 20/0.4 kV/kV (Gheorghe and Roșu, 2009).

Table 5

Transformer TTO-EPA 400 kVA – 20/0.4 kV/kV

Type of connection	No load losses P_0 $[W]$	Load losses P_K $[W]$	Impedance voltage, at 75°C u_K [%]	Total weight for core $[kg]$
Dyn5	*762*	*6025*	*3.92*	*641*

Table 5 presents the data obtained in the design process of transformer type TTO-EPA 400 kVA – 20/0.4 kV/kV (Gheorghe and Roșu, 2009).

3. Transformer with Windings of Bare Copper Conductors

A new perspective on the use of bare copper conductors for windings includes electrical and thermal modeling considerations. The cross-section of the core requires a large area, which means that a considerable part of the core window remains unused due to the curvature of the winding, the pipes can be wound semi-circularly and placed closer to the core inside the window area. The relative position of the winding terminations relative to each other does not affect the resulting leakage inductance. Sufficient space must be left between them to ensure adequate insulation (Djekanovic and Dujic, 2022).

4. Conclusions

It has been proven that the same winding and core designed for the conservator power distribution transformer can be recalculated and designed for hermetically sealed transformers, thus reducing the main dimensions.

The use of hollow copper pipes for the manufacture of transformer windings to replace the cooling system provided by radiators is not reliable. In the manufacturing process of the winding, when the pipe is bent per the bending radius, it will become thin thereby reducing the properties of copper pipes, and the soft hardness of the copper pipes will lead to the deformation of the coils.

To optimize and improve the performance of the distribution hermetically sealed transformers, we are going to impose the values and perform all the necessary calculations starting from the design, thus reducing the main dimensions.

REFERENCES

Altayef E., Anayi F., Packianather M.S., Kherif O., *On the Effects of Lamination Artificial Faults in a 15 kVA Three-Phase Transformer Core*, IEEE-INST Electrical Electronics Engineers INC 2023, 445, Hoes Lane, Piscataway, NJ 08855-414, IEEE Access, **10**, 19348-19355 (2022).

Djekanovic N., Dujic D., *Copper Pipes as Medium Frequency Transformer Windings*, IEEE-INST Electrical Electronics Engineers INC 2023, 445 Hoes Lane, Piscataway, NJ 08855-4141, Special Section on Power Electronics Emerging Technologies for Sustainable Energy Conservation, IEEE, **10**, 109431-109445 (2022).

Eslamian M., Kharezy M., Thiringer T., *An Accurate Method for Leakage Inductance Calculation of Shell Type Multi Core-Segment Transformers with Circular Windings*, IEEE-INST Electrical Electronics Engineers INC 2023, 445 Hoes Lane, Piscataway, NJ 08855-414, 2169-3536, IEEE Access, **9**, 111417-11143 (2021).

Gheorghe V.C., Roșu V., *Proiecte de transformatoare de distribuție*, (2009), Company Electroputere, www.electroputere.ro.

Kulkarni S.V., Khaparde S.A., *Transformer Engineering Design and Practice*, Indian Institute of Technology, Bombay Mumbai, India, Marcel Dekker, Inc., 270 Madison Avenue, New York, NY 10016, U.S.A. (2004).
Lee E.S., Park J.H., Kim M.Y., Han S.H., *An Integrated Transformer Design with a Center-Core Air-Gap for DAB Converters*, IEEE-INST Electrical Electronics Engineers INC 2023, 445 Hoes Lane, Piscataway, NJ 08855-414, IEEE Access, **9**, 121263-121278 (2021).
Li D.R., Zhang L., Li G.M., Lu Z.C., Zhou S.X., *Reducing the Core Loss of Amorphous Cores for Distribution Transformers*, Elsevier Science INC 2023, STE 800, 230 Park Ave, New York, NY 10169, 1002-0071, Progress in Natural Science-Materials International, China Mainland, **22**, 244-249 (2012).
Liu Y.B., Liang D., Wang Y.M., Zhang L.S., Li D.W., Gao Y.C., Wu Z.H., Wang C.X., Tang L.T., M*agnetic Integration and Modeling of Hybrid Distribution Transformer*, IEEE Energy Conversion Congress and Exposition 2021, 1269-1273.
Paithankar Y.G., *Transmission Network Protection Theory and Practice*, Visvesvaraya Regional College of Engineering Nagpur, India, Electric power systems-Protection I, Title 11, Series TK1010.P35, 1998, New York, Ed.1, Marcel Dekker, INC. 270 Madison Avenue, New York, 400 (2017).
Zhao Z., Wu Y., Diao F., Lin N., Du X., Zhao Y., Zhu G., *Design and Demonstration of a 100 kW High-Frequency Matrix Core Aircraft Power Distribution*, IEEE Energy Conversion Congress and Exposition 2022, New York, USA, 1269-1273.

ÎMBUNĂTĂȚIREA PERFORMANȚEI TRANSFORMATOARELOR DE DISTRIBUȚIE PENTRU SISTEMUL ENERGETIC

(Rezumat)

Progresele și evoluțiile rapide în proiectarea, modernizarea și optimizarea transformatoarelor au generat o creștere a puterii pentru liniile de distribuție, transformatoarele ocupând poziții importante în sistemul energetic național și internațional.

Această lucrare compară parametrii de ieșire generați de procesul de proiectare, valorile obținute între transformatoare de 400 kVA, un transformator de distribuție cu conservator și un transformator închis ermetic cu pernă de aer (EPA). Vom folosi aceeași construcție a miezului transformatorului cu coloane și juguri din fier cu cristale neorientate tăiate în unghi iar pentru bobine folosim conductor de cupru izolat cu hârtie. Se compară dimensiunile generale, masa totală a transformatoarelor, calculul de încălzire și randamentul acestora.

S-a dovedit ca toate materialele folosite la fabricarea unui transformator de distribuție trebuie să aibă proprietăți superioare, folosind cele mai noi materiale din domeniu creștem performanțele transformatoarelor de distribuție.