RESEARCH ARTICLE OPEN ACCESS

A Design Calculation for Single Phase Step Down Transformer

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Abstract:

This paper presents a design of a step-down transformer for supplying electrical power of output 10KVA, 250V and operating at a frequency of 50Hz. A precise calculation is made in designing the transformer such as window size, core area, thickness of yoke, number of turns and wire thickness of LT winding and HT winding, efficiency and overall transformer size such as length, width and height. The accurate calculation will give more efficiency of the transformer. High efficiency transformer is needed for good performance and to avoid the power loss. Power loss is high in low efficiency transformer.

Keywords **— shell type distribution transformer, LT winding, HT winding, window size, core area, thickness of yoke.**

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I. INTRODUCTION

We have designed an interesting single phase shell type distribution transformer of 10KVA, 1100/250V, 50Hz. A single-phase transformer consists of primary and secondary winding. The core of the transformer is made up of thin sheets (called laminations) of high grade of silicon. These laminations are provided in the transformer to reduce eddy-current loss, and the silicon steel reduces hysteresis loss. The laminations present in the transformer are insulated from one another by heat resistant enamel coating. L-type and E-type laminations are used for constructions.

There are two simple types of transformer constructions:
1. Shell type construction.
2. Core type construction.

Shell type construction:

In the shell type transformer, both the primary and secondary winding are wounded on the central limb, and the low reluctance path is completed by the outer limbs. Each winding is subdivided into sections. Low voltage (lv) and High voltage (hv) subsections are alternatively placed in the form of sandwich that is why this winding is also called sandwich or disc winding. The core is made up of two types of laminations. The laminations for the core type are U, and I-shaped. Firstly the U shaped laminations are stacked together for the required length. Half of the prewound low voltage coil is placed around the limbs. The lv coil is further provided with insulation. Then half of the prewound hv coil is placed around the lv coil. The core is then closed by the I-shaped laminations at the top. Forced air and/or forced oil cooling is essential in shell type transformer as heat generated during working, cannot get dissipated easily from windings due to surrounding yoke and limbs.

Core type construction:

In the core type transformer, the magnetic circuit consists of two vertical legs or limbs with two horizontal sections, called yokes. To minimize the leakage flux, half of each winding is placed on each leg of the core. The low voltage winding is placed next to the core, and the high voltage winding is placed around the low voltage winding to reduce the insulating material required. Thus, the two winding are arranged as concentric coils. Such type of winding is called as concentric winding or cylindrical winding.

II. DESIGN:

As given,

Output,Q=10Kva

Voltage/turn, $E_t = C\sqrt{Q}$ & C=1, for single phase shell type transformer.

Now, $E_t = 1\sqrt{10}$

$= 3.16$ volt

$E_t = 4.44\ f\ Øm$

$=> 3.16 = 4.44 \times Øm$

$=> Øm = \frac{3.16}{4.44 \times 50}$

$= 0.014$ wb

Let the maximum flux density in the core, Bm=1.1 wb/m^2

Net sectional area in the core, $A_i = \frac{Øm}{Bm} = \frac{0.014}{1.1}\ m^2$

$= 0.012 m^2$

$= 120 cm^2$

Gross sectional area in the core, $A_g = \frac{120}{0.9}\ cm^2$

$= 133.3\ cm^2$

As the area of A_g is small a rectangular section will be used the ratio of longer side to smaller side of the pole generally vary between 1.5 to 2.5

Taking this ratio to be equal to '2'

We have,

$$\frac{\text{core length(L)}}{\text{core width(W)}} = 2$$

Then $A_g = L.W$

$= 2WW$

$=> \frac{Ag}{2} = W^2$

$=> W = \sqrt{\frac{Ag}{2}} = \sqrt{\frac{133.3}{2}} = 8.16$ cm

Hence, L = 2W=2 x 8.16=16.32cm

Taking L =16 cm & W= 8cm, as the yoke carries half the core flux. We have thickness of yoke $= \frac{W}{2}$

$= \frac{8}{2} = 4$cm

Let A_w = Window area

K_w = Window factor

=0.26

∂= Current density

=2.2 Amp/mm^2

$$A_w = \frac{Q}{2.222\ f\ Bmax\ Ai\ Kw\ \partial \times 10^{-3}}\ m^2$$

$$= \frac{10}{2.222 \times 50 \times 1.1 \times 0.012 \times 0.26 \times 2.2 \times 10^6 \times 10^{-3}}\ m^2$$

$= 0.0131 m^2 = 131\ cm^2$

It is roughly divided into window height or width as follows;

Window height, H_w = 13 cm

Window width, $W_w = \frac{A_w}{H_w} = \frac{131}{13} = 10.07$ cm

$= 10$cm

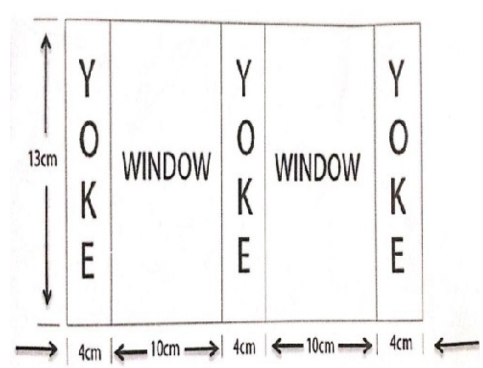


Figure 1. Yoke and Core arrangement.

LT winding:

Voltage at LT side, E_2 = 250 volt

No. of turns on secondary side, $N_2=\frac{E_2}{E_t}=\frac{250}{3.16}=79$

Now, we provide a total no. of turn which is more convenient or LT winding an arrange into section and same with HT windng between them.

LT turn per section=$\frac{80}{2}=40$

Full load current on 80 winding = $\frac{\text{output}}{\text{secondary winding}}$

$=\frac{10 \times 10^3}{250}$

= 40 ampere

Sectional area LT conductor, $A_2=\frac{I_2}{\partial}=\frac{40}{2.2}$ mm^2=18.2mm^2

Let us prefer copper strict as round section and leaving about 2cm for the end insulator, the length of core available for LT winding= $H_w - 2$

=13-2=11

Arranging 40 turn per LT section in two layer the length of core available is turn=$\frac{11 \times 10}{40+1}$

=2.68

Allowing about 0.5mm for fine insulator for both side, the thickness of strict copper=3-0.5=2.5

Depth of copper strict = $\frac{A_2}{2.5}$ = 7.28 mm

Taking the depth of copper strict approximately= 8mm to allow for the rounding of corner depth of copper strict with fine insulator=8+0.5=8.5mm

Depth of each LT section = 8.5 x 2 + 0.2(slack)

=17.2mm

HT winding:

Voltage at HT side, E_t= 1100 volt

No. of turns required for HT winding, $N_1=\frac{E_1}{E_t}$

$=\frac{1100}{3.16}$

=348

Effeciency, $\eta=\frac{\text{output}}{\text{input}}=\frac{10 \times 10^3}{E1\ I1}$, if E_1= primary voltage in volts

I_1 = secondary current in ampere

⇨ $I_1=\frac{10 \times 10^3}{\eta E_1}$

⇨ $I_1=\frac{10 \times 10^3}{0.96 \times 1100}$,taking η = 0.96

Therefore,I_1 = 9.5 ampere

Sectional area, $A_1=\frac{I_1}{\partial}=\frac{9.5}{2.2}$ mm, if current density,∂=2.2 ampere/mm^2

Therefore, A_1= 4.31mm^2

Taking round section and let d_1=diameter of HT conductor.

We have,

$\frac{\pi}{4}(d_1)^2 = A_1$

$\Rightarrow \frac{3.14}{4}(d_1)^2=4.31$

$\Rightarrow (d_1)^2=\frac{4A_1}{3.14}$

$=\frac{4 \times 4.31}{3.14}$

= 5.48mm

$d_1=\sqrt{5.48}$

therefore, d_1= 2.34 mm

Diameter of HT conductor with insulator=2.34+0.66

=3mm

Length of core available for HT winding = length of core for LT windimg – additional end insulator = 1.1-2=9cm.

Number of turns per layer = $\frac{9 \times 10}{3}=30$

Considering helical effect we can provide only 29 turn per layer. The number of layer required =$\frac{N_1}{29}$

$=\frac{348}{29}=12$

Therefore, the dewpth of HT winding =12 x d_1

=12 x 2.34=28.08mm

Depth of HT winding = no.layer x diameter of HT conductor + (no. of layer – 1) x 0.125 (empire cloth between layer) + 1(stack)

=12 x 2.34 + (12 -1) x 0.125 +1

=30.45mm

Width of HT winding = 3mm (former) + 0.25 (lateritic) + 2 x depth of each LT + 2 x 5(insulator between LT and HT winding) +0.25(tap) + 10 (clearance LT section and yoke) + depth of HT winding.

=3 x 0.25 + 2 x 17.2 + 2 x 5 + 0.25 + 10 + 28.08

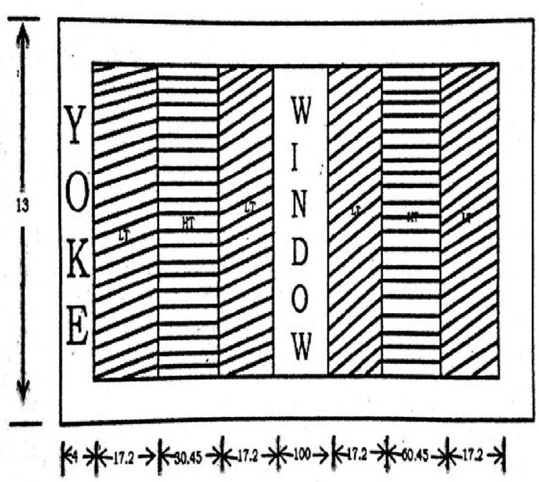
=88.35mm

=8.835cm, which is less than 10, the actual window with provided window width required = 3 (former) + 0.25 (latheroid) + 2 x depth of each LT + 2 x 5 (insulation between LT & HT winding) + 0.25 (tape) + 10(clearance between LT section & yoke) + depth of HT winding.

= 3+ 0.25 + 2 x 17.2 + 2 x 5 + 0.25 + 10 + 30.45

=88.35mm

=8.835cm, which is less than 10cm, the actual window width



all dimensions are in mm.
Figure 2. Arrangement of LT & HT winding

Overall transformer size:

Length of transformer= core length + 2 Ww

=16.32 + 2 x 10

=36.32 cm

Width of transformer = core width + 2 x Ww + 2 x thickness of yoke.

=8.16 + 2 x 10 + 2 x 4

=36.16 cm

Height of transformer = window height + 2 x thickness of yoke.

= 13 + 2 x 4

= 21cm

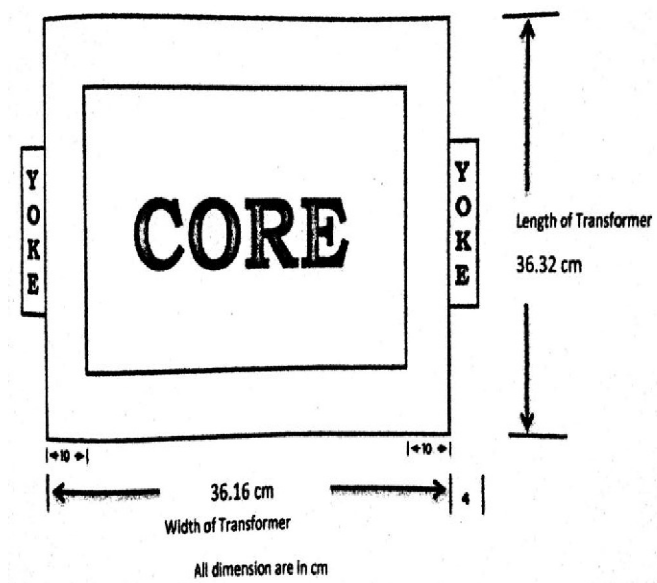


Figure 3. Length and width of transformer.

Size of tank:

Providing a clearance of 5cm between the vertical sides of the tank of transformer.

We have,

Length tank + length of transformer

=36.32 + 2 x 5

=46.32 cm

Width of tank = width of transformer + 2 x 5

= 36.16 + 2 x 5

= 46.16 = 46 cm. approx.

Leaving 2cm clearance at the bottom for piece 5cm at the top of all, 5cm at the top for the luminance.

We have,

Height of tank=height of transformer +2+5+5
= 21 + 12 =33 cm.

III.APPLICATIONS:

Shell type transformers are mainly used for low voltage applications and are very often used in low voltage power circuits as well as in electronic circuits. These transformers are also used to optimize the expenditure of a circuit since these transformers have square or rectangular cross-sectional core which costs less.

IV.ADVANTAGES:

Shell type transformers are more compact than core form of transformers, and have a great mechanical strength. Having great mechanical strength comes in to advantage here because, in an over current situation, the transformer is less prone to being damaged.

V.DISADVANTAGE:

Special fabrication facilities are required for the construction of a shell-type transformer due to its complexity and that leads to increased manufacturing and labour cost.

VI.CONCLUSION:

A single phase step down shell type transformer is proposed in this paper. This type of transformers can be easily employable for various low voltage applications. This system produces good result thereby reducing the size and complexity.

VII.REFERENCES:

[1] MS Calovic “Modeling and Analysis of Under-Load Tap-Changing Transformer Control Systems” IEEE Transactions on Power Apparatus and Systems (Volume: PAS-103, Issue: 7, July 1984)

[2] M.G. Say, The performance and Design of Alternating Current Machine, London: Pitman, pp.176-198, 1978

[3] K. M. Murthy Vishnu, Computer-Aided Design of Electrical Machines, Sultan Bazar: Adithya Art printers, pp.95-134, 2008.

[4] M. Rasheed, Power Electronics, Circuits, Device and Application (4th edition), New Delhi: Prentice Hall, pp. 378-388, 2013

[5] Stebbins, D. Rand., et al., ‚Dissolved Gas Analysis of Transformers Oil‛, Panel Session, 1997 Winter Meeting. PES/ IEEE, February 1997, NY

[6] Bak-Jensen, J., et al, ‚Detection of Faults and Aging Phenomena in Transformer by Transfer Functions‛, IEEE Transactions on Power Delivery, Vol. 10, No. 1, January 1995, pp. 308-314.

[7] Richard N. Anthony & Seema P. Navghare, “Introduction to Wireless Power Transfer”, International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-1, January 2016, ISSN: 2395-3470, Page 195-196

[8] Zhao Honggang, Zhang Xiuzeng, Liu Yue and Zou Benxia, "Monitoring system of isolation transformer power supply," IEEE 15T2008 Conference on Precision Electromagnetic Measurements Digest15T, Broomfield, CO, 2008, pp. 592-593

[9] www.bsigroup.com/Medical-Devices//EN-60601-Medical Electrical Equipment and Systems.