Applied Science and Engineering Journal for Advanced Research *Peer Reviewed and Refereed Journal*
ISSN (Online): 2583-2468
Volume-2 Issue-5 || September 2023 || PP. 29-34 DOI: 10.54741/asejar.2.5.5

Automatic Control and Mathematical models for Three Phase Transformer using MATLAB

Ankur Saxena[1] and Arvind Verma[2]
[1]*B.Tech Final Year Student, Department of ECE, MIT, Moradabad, Uttar Pradesh, India*
[2]*Assistant Professor, Department of ECE, MIT, Moradabad, Uttar Pradesh, India*

[1]*Corresponding Author: ankursaxena20031@gmail.com*

Received: 20-08-2023	Revised: 07-09-2023	Accepted: 25-09-2023

ABSTRACT
Our paper's primary goal is to use MATLAB to create a tool for transformer design. Manufacturers of transformers can expand their design capacity and save design man-hours by using the suggested methodology, which has several benefits. By running the values through the MATLAB software, we can construct a distribution transformer with any value (power, primary voltage/secondary voltage), a 50 HZ frequency, and a delta/star, shall and core type, oil immersed natural cooling design. In comparison to conventional methods using the same set of constraints, the dimensions as well as the active cost have been decreased. Therefore, this study shows how to use MATLAB to build power transformers in a better and more effective manner. Even though it is anticipated that the present power load will increase by 150% in 2017, it is challenging to find a solution to improve the capacity of facilities, particularly for power transformers. Using MATLAB to create a transformer design will be beneficial in the future.

Keywords: matlab, transformer, mathematical model

I. INTRODUCTION

Design of transformer using MATLAB has various advantages for transformer manufacturers, since they can increase their design capacity by it. Magnetic core and windings (or coils) are the two basic parts of any transformer. The core is made of silicon or sheet steel with 4 per cent silicon and laminated to reduce eddy current loss. It may be in either square or rectangular shape. It has two parts. The vertical portion on which the coil is wound is called the limb of the core, whereas the top and bottom horizontal portions are called the yoke. Figure shows the limb and yoke of the core.

The laminations are insulated from each other by a light coat of core plate varnish or by an oxide layer on the surface. The thickness of lamination is 0.35 mm for a frequency of 50 Hz and 0.5 mm for a frequency of 25 Hz.

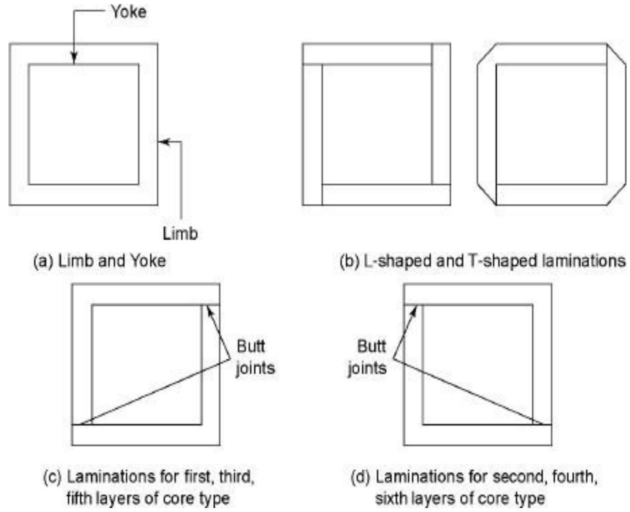

Figure 1

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research. MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving technical problems. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide. There are toolboxes for signal processing, symbolic computation, control theory, simulation and several other fields of applied science and engineering.

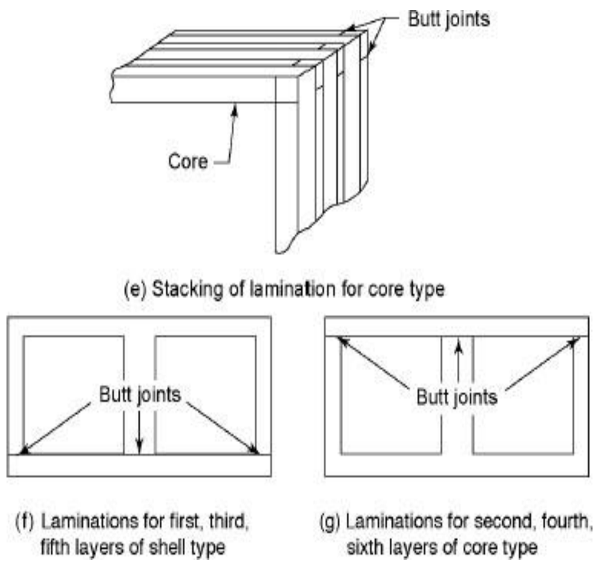

Figure 2

II. DESIGN OF TRANSFORMER

A 25 KVA, 11000/433 V, 50 Hz , 3 phase , delta/star, oil immersed natural cooled distribution transformer is designed by this paper. The transformer is provided with tapping's on the H.V winding. Maximum temperature rise not to exceed 45 degree Celsius .And we have adopted core type for the core. The transformer core , window , yoke ,frame, windings, losses, tank, leakage reactance and various other parts of the transformer is designed in this paper by using the MATLAB tools and calculations.

A. Specification of Core and Frame

Core type transformer generally uses rectangular or stepped core where as shell type uses rectangular core. Also core type distribution and small and medium power transformer uses rectangular core. the ratio of depth to width of the core varies between 1.4 to 2. Square core are used when circular coils are required for high voltage distribution transformer. On circular coils forces by excessive leakage flux due to short circuit are radial and there is no tendency for the coils to change its shape .But on rectangular coils forces are perpendicular to the conductor and tends to give the coil a circular shape. As the size of transformer increases it become wasteful to use rectangular coils hence in this paper we used stepped core.

Et=k*sqrt(Q)

Et is the voltage per turn and Q is the rating of transformer

Ai= max flux/Bm

Ai is the net core area required

max flux= Et/(4.44*f)

Agi=Ai/k

Agi is the gross core area

ki is the stacking factor

Kw=8/(30+KV),

Kw is the window space factor, it is the ratio of the copper area in the window of the total window area, it depends upon the relative amount of the insulation and copper provided which in turn depends upon the voltage rating and output of transformer.

Diameter of circumscribing circle,

$$D= sqrt(A\_i/.56)$$

$$Ai=0.56*D^2.$$

Q=3.33*f*Bm*delta*Aw*Ai*, output of the transformer.

Aw= Hw*Ww,

Aw is the area of the window,

Hw and Ww is the height and width of window. Distance between adjacent core centers:-

$$d=W\_w+D$$

$$Ay=(1.25 \text{ to } 1.5)*Agi,$$

Ay is the area of yoke. Area of the yoke is 15 to 25% larger than that of the core for hot rolled steel transformer, but of the same area as core in cold rolled grain oriented steel transformer.

$$W=2*d+a$$

d is distance between adjacent core center.

Height of yoke:-

$$H\_y=A\_y/D\_y$$

$$H=Hw+2*Hy,$$

H is height of frame and Hy is height of yoke.

Width of frame:-

$$W=(2*d)+s,$$

s is the width of laminations.

B. Windings of Transformer

Shell type of transformer use sand which type of windings with coils pancakes. Core type use concentric type of winding i.e cylindrical, helical ,cross-over or disc type .Helical winding are used for L.V of medium and high capacity transformer where as cross – over windings are used for H.V of small transformer, these windings are used in this paper for H.V and L.V. The area of conductors in primary and the secondary windings is determined after choosing a suitable current density to be used in the windings temperature rise in the windings may become excessive if higher values of current density are chosen and this may cause injury to the insulation. Hence the choice of current density is important in this paper as the I^2*R losses and the load at which the maximum efficiency occurs depends on it. For minimum I^2*R losses , the value of current density in each of the two windings should be equal.

$$T=V/Et, \text{ T is the turns of winding}$$

$$I=KVA \text{ per phase}*10^3/V$$

I is the current in windings

$$a=I/delta$$

a is the area of conductor in the windings

$$Din=(d+2*I)$$

Din is inside diameter of l.v winding

dis radial depth of L.V winding

I is insulation between L.V winding and core

$$Dout=(Din+2*Rd2)$$

Dout is outside diameter of l.v winding

Rd2 is radial depth of L.V winding

C. Losses and Efficiency

The specific iron loss is Pi=kh*f*Bm^2+kt*f^2*Bm^2 and eddy current loss is Pe=ke*f^2*Bm^2.We have hysteresis losses are PH+kh*f*Bm^2.

The total losses decrease if the frequency increased and the applied voltage is kept constant, hence with increased frequency we can afford to have more I^2*R loss and thus for the same loss the rating of the transformer can be increased.

Total I^2*R loss =3*I^2*R + stray load loss

stray load losses=15% of I^2*R losses

Total Core loss= losses in limb + losses in yoke

Total losses= Core loss + I^2*R loss

Efficiency=output/(output+loss)

The maximum efficiency occurs at sqrt(Pi/Pc) percent of full load .No load current Io consists of two components ,magnetizing current Im and loss component Il, Io= sqrt (Im^2 +Il^2).

Total magnetizingmmf,

Tmmf=2*atc*lc+2*aty*ly

aty is magnetizing mmf in the yoke

atc is magnetizing mmf in the core.Length of flux path through the core lc=H_w

Length of flux path through the yoke, ly=W.

D. Specification of Tank

Tank bodies of the transformers are made up from rolled steel plates which ae fabricated to form the container. Small tanks are welded from steel plates while larger ones are assembled from boiler plates. Tanks are provided with lifting lugs,small transformers have cooling tubes let into the vertical sides, but large transformers require separate banks of cooling tubes. Such transformers have plain tanks with provision for pipes and valves to direct and control the oil flow. While designing tanks for the transformer a large number of factors have to be considered such as weight, stray load losses and cost should be considered. The tank should be strong enough to withstand stresses produced by jacking and lifting. The size of the tank is taken large enough to accommodate cores, windings, internal connections and also must the requisite clearance between the windings and the walls. The use of aluminum yanks in place of steel reduces the stray magnetic fields and consequently the stray load loss. The temperature rises as calculated with plain tanks exceeds the specified limit, but it brought down by the provision of tubes, it increases the dissipation area. Height of the Tank Ht=(H+h)/1000, h is clearance between assembled transformer and tank,H is Height of the frame width of the Tank Width of the Tank in meters, Wt=(2*D+dout+2*l)/1000,dout is outside diameter of h..v winding. Length of the Tank Lt=(dout+2*l)/1000,l is clearance on each side between winding and tank along the width. clearance along the length of the transformer i.e l is greater than that clearance along the width of the transformer this is because additional space is needed along the length to accommodate tappings. Z is the clearance between H.V winding and tank, h is the clearance between assembled transformer and tank. Total loss dissipating surface of the Tank St=2*(Wt+Lt)*Ht. Temperature rise with tubes theta=TL_fl/(St*SL). If the value of the theta is below 35 degree Celsius than plain tank is sufficient for cooling and no extra tubes are required for cooling of the Tank.

Figure 3: Body of transformer

ISSN (Online): 2583-2468
Volume-2 Issue-5 || September 2023 || PP. 29-34 DOI: 10.54741/asejar.2.5.5

Figure 4: Transformer tank

III. DESIGN RESULT OF TRANSFORMER WITH MATLAB

Type of winding	Helical	Cross-over
Area	14.9 mm^2	0.312 mm^2
Total number of coils	3	3*8
Number of layers	3	24
Length of mean turns	0.468 m	0.666 m
Height of winding	285 mm	221 mm
Depth of winding	9.1 mm	26 mm
Current density	2.23 A/mm^2	2.43 A/mm^2

Table 1: result of transformer design

Insulation

Between l.v winding and core	Press board wraps 1.5 mm
Between l.v winding and h.v winding	Bakelized paper 5mm
Width of duct between l.v and h.v	5 mm

Tank

Dimensions Height Ht Length Lt width Wt	 0.951 m 0.35 m 0.84 m
Oil level	0.728 m
Tubes	Nil
Temperature rise	31.9 degree Celsius

Impedance

P.U Resistance	0.025
P.U Reactance	0.0406
P.U Impedance	0.444

Losses

Total core loss	181 W
Total copper loss	720 W
Total losses at full load	901 W
Efficiency at full load and u.p.f.	96.5%

Frame

Distance between adjacent limbs	d	255 mm
Height of frame	H	536 mm
Width of frame	W	624 mm
Depth of frame	Dy	114 mm

Window

Number		2
Window space factor	Kw	0.18
Height of window	Hw	300 mm
Width of window	Ww	120 mm
Window area	Aw	36*10^3 mm^2

Yoke

Depth of yoke Dy	114 mm
Height of yoke Hy	114 mm
Net yoke area	12.168*10^3 mm^2
Flux density	0.833 Wb/m^2
Flux	10.135 m Wb
Weight	115.3 kg
Specific iron loss	0.8 W/kg
Iron loss	98 W

IV. CONCLUSION

The 25KVA, 11000/433 V transformer's efficiency is at 96.5%. About 720 W and 181 W, respectively, are lost due to copper and iron, respectively. The circumscribing circle's diameter is 135 mm, and the core's net iron area is 10.135*10-3 mm2. Yoke dimensions are 114 mm in depth and 114 mm in height, with a net area of 12.16*10 3 mm2.The window measures 300 mm in height, 120 mm in breadth, and 36 x 10 3 mm in area.

REFERENCES

1. S. W. Lee, W. S. Kim, S. Y. Han, Y. I. Hwang, & K. D. Choi. (2006). Conceptual design of a single phase 33 MVA HTS transformer with a tertiary winding. *The Korean Superconductivity Society*, *7*(2), 162–166.
2. W.-S. Kim et al. (2005). Fabrication and test of multiple HTS wire with transposition for HTS power transformer. *Magnet Technology, 19*.
3. Y.-I. Hwang et al. (2005). Continuous disk type HTS winding of high voltage power transformer. *Magnet Technology, 19*.
4. M. Wilson. (1983). *Superconducting magnet*. New York: Clarendon Press.