MANUFACTURING, DESIGNING AND ANALYSIS OF TRANSFORMER CORE

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Abstract:
Transformer is based on the principal of mutual induction from primary winding to secondary winding due to alternating current. The design calculation of transformer is a hectic process when done manually. Since the calculation is long and interdependent with each steps the occurrence of error is more likely so use of computation system can minimize the error. For this use of MATLAB to have a software to design the transformer providing the design parameter is the main objective of the paper. With the Graphical user interface (GUI) and app designer helps to simplify the process and make it more user friendly which provide space for input values and options to choose. The software make calculation regarding the dimension, efficiency and manufacturing cost of the specified transformer. In this research paper,manufacturing, designing and analysis of transformer coreis done. The paper includes data collection and simulation about transformer core, Electrical steel, LV & HV windings and simulation is done in MATLAB software. Core is manufactured using CRGO steel. The transformer designing process includes Customer's requirement, Material selection, Dimensioning, LV-HV windings, etc. By this data collection and simulation, we were able to simulate Transformer Designing using C language in MATLAB software.

***Keywords:*CRGO, MATLAB, Graphical user interface, LV and HV winding, mutual induction**

1. INTRODUCTION

For the manufacturing of Transformers, the raw material that is Cold Rolled Grain Oriented (CRGO) silicon steel roll. Then as per requirement – the thickness & grade of CRGO used for core building are included. In further step, Laboratory tests are being conducted on the selected material. After lab testing, dimensions for building of yoke, limb and side limb are selected as per requirement for slitting and cutting process. In slitting and cutting procedure few checks are being done to maintain the quality of core building. After cutting process, transformer assembly is carried out.

2. CONCEPT

Our main purpose of this research paper is to develop a simulation program for designing of Transformer, which will be helpful in calculations such as design of magnetic frame, no load current, design of LV & HV windings, performance calculations and tank design & weights.

3. DESIGN OF CORE

For Core type transformer the cross section may be rectangular, square or stepped. Generally circular cores are used to for LV & HV windings of the transformer, because of better mechanical strength, which indicate theoretically that a circular core should be used. It is very complicated to manufacture a circular core and as a result the stepped cores are generally used. In case of small transformers, a square core can be used but for large transformers, stepped core is used in order to fully utilize the available space, which means smaller diameter of the circumscribing circle over the stepped core. Hence the length of mean turn of the windings will be reduced which results in saving of copper material for the windings. However, with larger number f steps used for the core, labor charges for shearing and assembling different laminations will increase appreciably. Thus a compromise has to be made between these factors to decide the number of steps. The number of steps will depend up on the KVA rating of the transformer.

3.1. Square Core

Let, d = diameter of circumscribing circle
Also, d = diagonal of the square core
a = side of core = d $\sin 45^{o}$ = 0.71d
A_{gi} = gross core area= $a^2 = (0.71d)^2 = 0.5d^2$
Let Stacking factor, $S_f = 0.9$
Net Core Area, A_i = Stacking factor x gross core area = $0.9 \times 0.5d^2$
= $0.45d^2$
The ratio, Net Core Area/Area of Circumscribing Circle = $0.45d^2/(\pi/4)d^2$
= 0.58
The ratio, Gross Core Area/Area of Circumscribing Circle = $0.5d^2/(\pi/4)d^2$
= 0.64
Core Area factor, K_c = Net Core Area/Square of Circumscribing Circle
$K_c = A_i/d^2 = 0.45d^2/d^2 = 0.45$

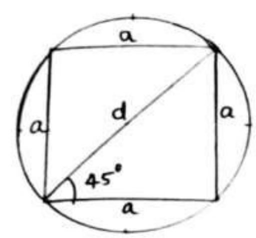

Fig. 1 – Cross-section of Square core

3.2. Stepped Cores

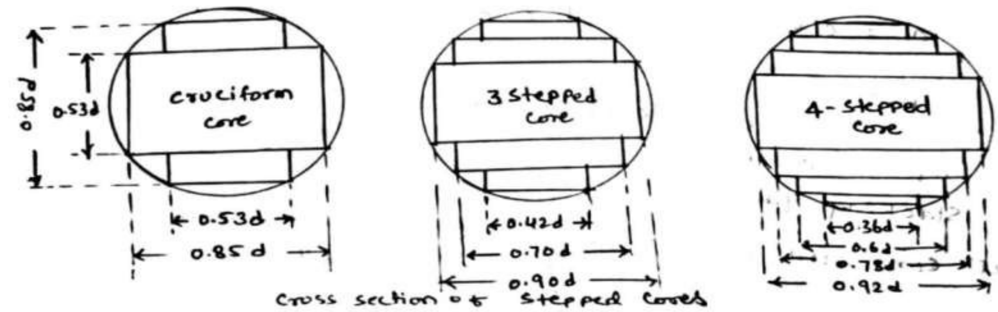

Fig. 2 – Cross-section of Stepped Cores

Table-1

Comparison of different types of Cores

Ratio	Square Core	2-Stepped Core	3-Stepped Core	4-Stepped Core
A_{gi}/Area of circumscribing circle	0.64	0.79	0.84	0.87
A_i/Area of circumscribing circle	0.58	0.71	0.75	0.78
Core area factor $K_c = A_i/d^2$	0.45	0.56	0.60	0.62

4. INSULATORS

There few materials used to as insulators in transformer cores, namely:

i. **PCB Insulation**
PCB having high purity with excellent electrical & mechanical properties, is specifically produced for the high voltage & extra high voltage transformers. PCB have high dielectric strength & is used as insulating material in different types of Power & Distribution Transformers.

ii. **Cotton Insulation Tapes**
Cotton Insulation Tapes is made from pure cotton fibre and can be used for electric motor, coil of transformers and other appliances. cotton tape can be used as binding materials because of good mechanical strength and insulating quality.

iii. **Fiber Glass Insulation**
Fiberglass insulation tape is made of non-alkali glass fiber yarn. It is woven by twisted strands of fiberglass at right angles to one another, having the highest glass-resin ratio and mechanical strength of all fiberglass insulation materials.

iv. **Insulating Varnish**

Insulating varnishes are resins like epoxies or alkyds used to protect high voltage machines such as transformers, motors and generators from electrical failure. They are applied over electrical conductors to provide a layer of electrical isolation and prevent shorting. While very similar to conformal coatings, these systems have superior dielectric properties, which makes them a better choice for applications like insulating windings and coils.

5. CORE TYPE POWER TRANSFORMER

Total design is split into six parts in a proper sequence. Design Calculations are given for a given Rating of a Transformer, followed by Computer Program written in C language using MATLAB software for each part. Finally all the Programs are added together to get the total Program by running which we get the total design. Computer output of total design is given. This design may not be the optimum one.

Problem : Design a 800 KVA, 6600/ 440 V, 50 Hz,3 Phase, Delta/Star, Core Type, ON Cooled Power Transformer: (limit temp-rise to 50 deg-C).

5.1. Steps for Design of Each Part

(a) Calculate the dimensions of Magnetic frame consisting of core, window and yoke. Calculate flux densities in those parts and iron losses.
(b) Calculate Amp-Turns and no load current.
(c) Calculate number of turns, size of copper and final dimensions of LV winding.
(d) Calculate number of turns, size of copper and final dimensions of HV winding.
(e) Check weather clearances between magnetic frame and windings are OK.
(f) Calculate Windings copper Losses, total losses, efficiency, reactances and % regulation.
(g) Calculate dimensions of cooling tank, number and size of cooling tubes, temperature rise, total weight and Kg/KVA.

5.2. Magnetic Frame

Assuming 3 stepped core with factor (k) = 0.6 and Value factor (K) = 0.6,
Volts/tum (Et) = k x √(KVA/ph) = 0.6 x √(800/3) = 9.798
Assuming Max. Flux density in Core (Bm) = 1.5 T,

$$\text{CS area of Core (Ai)} = \frac{Et}{4.44 \times f \times Bm} = \frac{9.798}{4.44 \times 50 \times 1.5} = 0.0294\ m^2$$

Assuming Average Current density (cdav) = 2.6 A/mm^2

$$\text{Window Space factor (kw)} = \frac{10 \times 1.15}{30 + KV} = \frac{10 \times 1.15}{30+6600/1000} = 0.314$$

$$\text{Window Area (Aw)} = \frac{KVA \times 1000}{3.33 \times f \times Bm \times kw \times cdav \times 10^6 \times Ai} = \frac{800 \times 1000}{3.33 \times 50 \times 1.5 \times 0.314 \times 2.6 \times 10^6 \times 0.0317} = 0.1235\ m^2$$

$$\text{Assuming Length of Core (L)} = \frac{Aw}{D - d} = \frac{0.1235}{0.44 - 0.23} = 0.5883 = 0.59\ m$$

Length of Yoke(W) = (2 x D) + (0.9 x d) = (2 x 0.44) + (0.9 x 0.23) = 1.1m
Width of Yoke (by) = 0.9 x d = 0.9 x 0.23 = 0.207 m

Height of Yoke (hy) = Ay/by = 0.0397/0.207 = 0.1917 m
From Fig. 3,
Loss in Core corresponding to Bm = 1.5T (WpKgC) = 1.6 W/Kg
Weight of Core (KgC) = Ph x Ac x L x 7.55 x 1000
= 3 x 0.0345 x 0.59 x 7.55 x 1000 = 461.04 Kg
Iron Loss in Core (PiC) = WpKgC x KgC = 1.6 x 461.04 = 737.67 W
Flux density in Yoke (By) = Ac/Ay x Bm
= 0.0345/0.0397 x 1.5 = 1.3043 T
Loss in Core corresponding to By = 1.3043T (WpKgY) = 1.009 W/Kg
Iron Loss in Yoke (PiY) = WpKgY x KgY
= 1.009 x 659 = 664.73 W

Considering 5% extra,
Total Iron Loss (Pi) = 1.05 x (PiC + PiY)/1000= 1.05 x (737.67 + 664.73)/1000 = 1.4725 KW

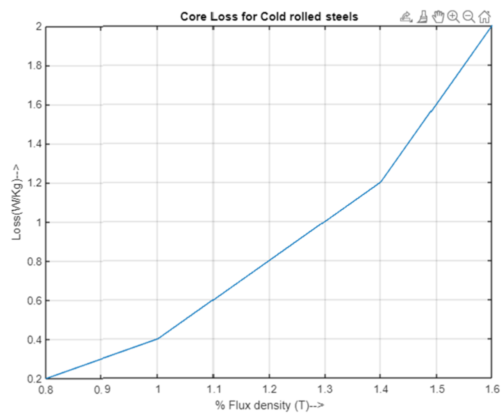

Fig. 3 – Core Loss for Cold Rolled Steels

5.3. No-Load Current

From Fig. 4,
AT/m for Core corresponding to Bm = 1.5T (atC) = 150 AT/m
AT for Core (ATC) = Ph x at C x L = 3 x 150 x 0.59 = 265.5
AT for Yoke (ATY) = 2 x at Y x W = 2 x 109.6 x 1.1 = 241.12
Total AT/phase (ATpPh) = (ATC + ATY)/Ph
= (265.5 + 241.12)/3 = 168.87

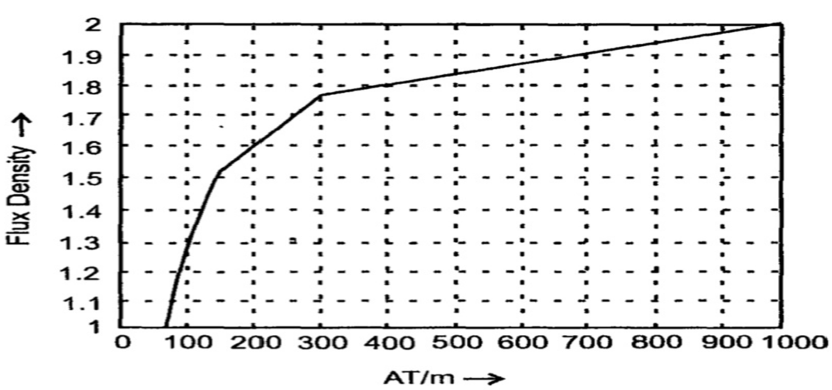

Fig. 4 – Core Loss for CRGOs

No. of Turns in LV wdg (T2) = $\frac{LV}{\sqrt{3} \times Et} = \frac{440}{\sqrt{3} \times 10.57}$ = 24.03 = 24

Phase Current m LV Wdg (I2) = $\frac{KVA \times 1000}{\sqrt{3} \times LV} = \frac{800 \times 1000}{\sqrt{3} \times 440}$ = 1049.7 A

Magnetizing current (Im) = $\frac{1.15 \times ATpPh}{\sqrt{2} \times T2} = \frac{1.15 \times 168.87}{\sqrt{2} \times 24}$ = 5.7218 A

No load Current (I0) = $\sqrt{(Iw^2 + Im^2)} = \sqrt{(1.9322^2 + 5.7218^2)}$ = 6.0392 A

Ratio of I0/I2 (I0byI2) = 10/12 x 100 = 6.03921/1049.7 x 100

= 0.5753 (Lies between 0.5 to 1 and hence OK).

5.4. LV Winding

Assume :

1. Space available for turns (ALW) = 80% length
   = 0.8 x L = 0.8 x 0.59 = 0.472 m = 472 mm
2. 2 turns radially (T2r) and
   [T2a = T2/T2r = 24/2 = 12] Axially/Length-wise
3. Since 1049.7 Amps very high, 12 parallel strands (stP) in each conductor.

Since 12 turns are accommodated in a length of 472 mm,

space/turn (ALT) = 472/12 = 39.3 mm

Since we can not have a single strand of 39.3 mm, let us select 3 strands (NstA = 3) axially

No. of strands radially (NstR) = stP/NstA = 12/3 = 4

Hence width of each strand (stW) = (ALT/NstA) – 0.5

= (39.3/3) – 0.5 = 12.6 = 12 mm (bare)

CS area of conductor (a2) = stW x stT x stP x 0.98

= 12 x 3 x 12 x 0.98 = 423.36 mm^2

Current Density (cdLV) = 12/a2 = 1049.7/423.36

= 2.48 A/mm^2 (lies between 2.3 to 3.5 and hence OK)

Radial Width of the winding (rwLV)=NstR x (stT + 0.4) x T2r + 1.8

= 4 x (3 + 0.4) x 2 + 1.8 = 29 mm

Inner dia of LV wdg (di2) = d x 1000 + 2 x (5 + 3 + 5)

= 0.23 x 1000 + 2x (13) = 256 mm;

Outer dia of LV wdg (do2) = di2 + 2 x rwLV

= 256 + 2 x 29 = 314 mm;

Mean length of LV winding (Lmt2) = $\frac{\pi \times (di2 + do2)}{2 \times 1000}$

= $\frac{\pi \times (256+314)}{2 \times 1000}$ = 0.8954 m

Res of LV wdg/ph (r2) = 0.02 x Lmt2 x T2/a2

= 0.02 x 0.8954 x 24/423.36 = 1.0151 mΩ

Copper loss in LV wdg(pcu2) = Ph x $I2^2$ x r2/1000

= 3 x 1049.7^2 x 1.0151 x 10^{-6} = 3.356 KW

5.5. HV Winding

No. of turns/ph (TI) = T2 x HV/LV x √3

= 24 x 6600/440 x √3 = 623.5 = 624 (rounded oft)

Phase current in HV Wdg (I1) = $\frac{KVA \times 1000}{3 \times HV} = \frac{800 \times 1000}{3 \times 6600}$ = 40.404 A

Disc type winding with rectangular cross section is used

Assuming "z-2" no. of coils will have "x" no. of turns and 2 coils (both are in either end) will have "0.65 x z",

Total no. of turns (T1) = x(z – 2) + 2 x 0.65 x x

from which x = T1/(z – 2 + 1.3);

No. of turns in 12 coils (xl) = $\frac{T1}{AxC - 2 + 1.3}$

= $\frac{624}{14 - 2 + 1.3}$ = 46.9= 48

No. of turns in each of the 2 end coils(x3)

= [TI – {x2 x cA x (AxC–2)}]/2

= [624 – {12 x 4 x (14 – 2)}]/2 = 24

Space available per coil (ALPC) = ALW/A x C = 413/14 = 29.5 mm

Space for each strand (ALPC1) = ALPC/cA = 29.5/4 = 7.375 mm

Strand width (stW1) = ALPC1 – 0.4 = 7.375 – 0.4 = 6.975 mm;

Select 6 mm;

Assuming current density (cdHV) = cdav + 0.2

= 2.6 + 0.2 = 2.8 A/mm^2

CS area of conductor in a turn (a1) = I1/cdHV

= 40.404/2.8 = 14.43 mm^2

Thickness of strand in a turn (stT1) = a1/stW1

= 14.43/6 = 2.405, say 2.5 mm

Current density (cdHV) = I1/a1 = 40.404/14.7 = 2.749 A/mm^2

Assuming 6mm insulation between coils,

Axial length occupied by all strands (AxLw)

= AxC x aLc + (AxC – I) x 6 = 14 x 25.6 + (14–1) x 6

= 436.6 mm

Assuming 30mm gun metal end ring and 100mm end insulation, Axial Length (AxL) = AxLw + 30 + 100 = 436.6 + 130 = 566.4 mm

Inside dia oh HV wdg (di1) = do2 + 2 x (5 + 6 + 5)

= 314 + 32 = 346 mm

Outer dia of HV winding (do1) = di1 + (2 x rwHV)

= 346 + 2 x 34.8 = 415.6 mm

Mean length of HV turns (Lmt1) = π x (di1 + do1)/(2 x 1000)

= π x (346 + 415.6)/2000 = 1.1963 m

Res of HV wdg/ph(rl) = 0.02 x Lmt1 x T1/a1

= 0.02 x 1.1963 x 624/14.7 = 1.0156 Ω

Copper loss in HV Wdg (pcul) = 3 x 11^2 x rl/1000= 3 x 40.404^2 x rl/1000

= 1.0156/1000 = 4.9741 KW

5.6. Performance

Assuming stray losses as 5%,

Total Wdg Copper losses (pcuT)

= 1.05 x (pcu1 + pcu2)

= 1.05 x (4.974 + 3.356) = 8.746 KW

Total losses on Full Load (ptFL) = (pcuT + Pi)= 8.746 + 1.473 = 10.219 KW;

Efficiency Calculation for 1stvariant :

Pf = 1.0 ; Ldpu = 1.0

Total Loss (TL) = Pi + (pcuT x Ldpu^2)

= 1.473 + (8.746 x 1.0^2)

= 10.219 KW

Output (Opt) = Ldpu x KVA x pf = 1.0 x 800 x 1.0 = 800 KW

Input (lnp) = Opt + TL = 800 + 10.219 = 810.219 KW

Efficiency(eft) = Opt/Inp x 100 = 800/810.219 x 100
= 98.7387 %

Load for max. Efiiciency (Ldmxef) = √(Pi/pcuT) x KVA= √(1.473/8.746) x 800
= 328.25 KVA

Max Efficiency (efmx)

$$= \frac{Ldmxef \times 0.85}{(Ldmxef \times 0.85) + (2 \times Pi)}$$

$$= \frac{328.25 \times 0.85}{(328.25 \times 0.85) + (2 \times 1.473)} = 0.9895 \text{ pu} = 98.96\ \%$$

P.U. Reactance (Ex)

$$= \frac{2 \times \pi^2 \times f \times 4 \times 10^{-7} \times Lmt \times AT}{Lc \times Et} \times 0.016 + \frac{rwHV + rwLV}{3 \times 1000}$$

$$= \frac{2 \times \pi^2 \times 50 \times 4 \times 10^{-7} \times 1.048 \times 25212}{0.4364 \times 10.57} \times 0.01\ 6 + \frac{29 + 34.8}{3 \times 1000}\Bigg]$$

= 0.0841 pu

P.U. Resistance (Er) = pcuT/KVA
= 8.746/800
= 0.0109

P.U. Impedance (Ez) = $\sqrt{(Er^2 + Ex^2)}$
= $\sqrt{(0.0109^2 + 0.0841^2)}$
= 0.0848 pu

Regulation at 0.85 pf and FL (Reg85) = Er x 0.85 + Ex x $\sqrt{(1 - 0.85^2)}$
= 0.0109 x 0.85 + 0.0849 x $\sqrt{(1 - 0.85^2)}$
= 0.0536pu (5.36%)

Regulation at UPF and FL (RegUPF) = Er
= 0.0109 pu (1.09%)

5.7. Tank Design

Assuming Length-wise clearance (dL) = 140 mm,

Length of Tank (Lt) = 2 x D x 1000 + (do1 + dL)= 2 x 0.44 x 1000 + (415.6 + 140)
= 1435.6 mm

Width of Tank (bt) = do1 + dB= 415.6 + 180 = 595.6 mm

Height of Tank (ht) = L x 1000 + (2 x hy x 1000 + dH)
= 0.59 x 1000 + (2 x 0.1917 x 1000 + 500)
= 1473.3 mm;

Volume of Tank (Vt) = Lt x bt x ht/10^9
= 1435.6 x 595.6 x 1473.3/10^9
= 1.2598 m^3

Temperature-rise of Tank (Tr) $= \frac{ptFL \times 1000}{12.5 \times St}$

$$= \frac{10.219 \times 1000}{12.5 \times 5.9853} = 136.6\ °C$$

Required Tube Cooling Area (CAt)
= (ptFL x 1000–12.5 x St x TRP)/(6.5 x TRP x 1.35)
= (10.219 x 1000–12.5 x 5.9853 x 50)/(6.5 x 50 x 1.35)
= 14.765 m^2

No. of cooling tubes required (Nt) = 14.765/0.1571 = 94

Wt. of Copper in HV wdg (Wcul) = 8.9 x Lmt1 x Tn LV w1 x a1/1000
= 8.9 x 1.1963 x 624 x 14.7/1000
= 97.665 Kg

Wt. of Copper in LV dg(Wcu2) = 8.9 x Lmt2 x T2 x a2/1000
= 8.9 x 0.8954 x 24 x 423.36/1000

= 80.967 Kg

Wt. of Iron (Wiron) = KgC + KgY= 461 + 659 = 1120 Kg;

Assuming 1% Insulation Wt, Total Weight (Wtot)

= 1.01 x (Wcu1 + Wcu2 + Wiron)

= 1.01 x (97.665 + 80.967 + 1120)

= 1311.6 Kg

Specific Wt (KgPkva) =WtotlKVA= 1311.6/800= 1.6395

6. MATLAB PROGRAM USING 'C' LANGUAGE

To Design a 800 KVA, 6600/ 440 V, 50 Hz,3 Phase, Delta/Star, Core Type, ON Cooled Power Transformer: (limit temp-rise to 50 deg-C).

Program :

```
    % Design of Core Type Power Transformer
    KVA = 800; HV = 6600; LV = 440; f = 50; Ph = 3; % Input Data
    f2 = fopen('Total_800KVA_Output.m', 'w');
fprintf(f2, '% 3d KVA, % 5d, % 4d V, % 2d Hz, % 1d Phase,Delta/Star, Core Type,
      ON cooled Power Transformer:\n', KVA, HV, LV, f, Ph);
fprintf(f2, '===================================\n');
fprintf(f2, '<-----1) Design of Magnetic Frame---------------------------- >\n');
    k = 0.6; ki = 0.92; K = 0.6; Bm = 1.5; cdav = 2.6; LbyD = 2.8;
    % Assumptions
    Et = K*sqrt (KVA/Ph); Ail = Et/ (4.44*f*Bm); dl = sqrt (Ail/k);
    d = ceil (dl*100) /100;
    Ai = k*d^2; Et = 4.44*f*Bm*Ai; kw = 10/(30+ HV/1e3)*1.15;
    Aw = KVA*1e3/(3.33*f*Bm*kw*cdav*1e6*Ai); L1 = sqrt(LbyD*Aw);
    L = ceil(L1*100)/100; D1 = Aw/L+d; D = ceil(D1*100)/100;
LbyD = L/(D-d); W1 = 2*D + 0.9*d; W = ceil(W1*10)/10;
    Ac = Ai/ki; Ay = 1.15*Ac; by = 0.9*d; hy = Ay/by;
fprintf(f2, 'Assumed: For 3stepped Core factor(k) = % 4.2f, Value factor (K) =
      % 4.2f\n', k, K);
fprintf(f2,'Window Area (sq.m) % 6.4f\n', Aw);
fprintf(f2, 'Length of core (L)(m) % 6.4f\n', L);
fprintf(f2, 'Oistbetw Core-Centres (D) (m) % 6.4f\n', D);
fprintf(f2, 'L/(D-d) ratio % 6.4f (Permissible: 2.5 to 4)\n', LbyD)
title ('Core Loss for Cold rolled steels'); %
WpKgY = interp1 (BB, WpKg, By, 'linear' ); PiY = WpKgY*KgY;
fprintf(f2, 'Flux Dens in Yoke (T) % 6.4f\n', By);
fprintf(f2, 'Total Iron Loss (KW) % 6.3f\n', Pi);
fprintf (f2,' <-----2) No-Load Current----------------------------- >\n');
    B1 = [1 1.25 1.5 1.75 2.0];
    H1 = [70 100 150 300 1000]; % for Cold Rolled
    % plot (H1, B1); grid; xlabel ('AT/m-->'); ylabel ('Flux density (T)-->');
Iw = Pi*1000/(sqrt(3)*LV); Im = 1.15*ATpPh/sqrt(2)/T2;
    I0 = sqrt(Im^2 + Iw^2);
    I0byI2 = I0/I2*100;
fprintf (f2, 'AT/phase: % 6.2f\n', ATpPh);
fprintf(f2, 'Turns in LV winding % 6.0f\n', T2);
fprintf(f2,' Ratio of IO/I2 (perc) % 6.3f (Permissible: 0.5 to 1)\n', I0byI2);
fprintf (f2, '<-----3) Design of LV Winding----------- >\n');
    T2r = 2; stP = 12; NstA = 3; stT = 3;
rwLV = NstR*(stT+ 0.4)*T2r + 1.8; di2 = d*1000 + 2*(5 + 3 + 5);
    do2 = di2 + 2*rwLV; Lmt2 = pi*(di2 + do2)/2e3;
    r2 = 0.02*Lmt2*T2/a2; pcu2 = Ph*I2^2*r2/1000;
fprintf (f2,'Turns (RadialXAxial) % 2.0f X % 2.0f \n', T2r, T2a) ;
fprintf (f2, 'Strands (RadialXAxial) % 2.0f X % 2.0f\n', NstR, NstA) ;
fprintf (f2, 'Axial Slack in LV-Wdg (mm) % 6.2f (desirable>7)\n', SlkLVax);
fprintf (f2, 'Radial width of Wdg (rom) % 6.2f\n', rwLV);
fprintf (f2, 'Resistance/phase (m.ohm) % 6.4f\n',r2*1000);
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```
fprintf (f2, 'Cu.Loss in LV wdg (KW)% 6.3f\n', pcu2);
fprintf (f2, '<-----------4) Design of HV Winding------------ >\n');
    T1a = T2*HV/LV*sqrt(3); T1 = ceil(T1a); I1 = KVA*1e3/(3*HV);
cA = 4; AxC = 14; cdHV = cdav + 0.2; % Assumptions
    xl = T1/(AxC - 2 + 1.3) ; x2 = ceil (xl/cA) ;
    x3 = (T1-(x2*cA*(AxC-2)))/2; Tlx = (AxC-2)*cA*x2 + 2*x3;
cR = x2; ALW1 = floor (0.7*L*1000); ALPC = ALW1/AxC;
    ALPC1 = ALPC/cA; stW11 = ALPC1-0.4;
    stW1 = floor (stW11); a1a = I1/cdHV; stT11 = a1a/stW1;
    Lmt1 = pi* (di1 + do1)/2e3; r1 = 0.02*Lmt1*T1/a1;
    pcu1 = 3*I1^2*r1/1000;
fprintf (f2, 'Turns in HV Wdg % 6.0f\n', T1);
fprintf (f2, 'Ph-Current in HV wdg (Amp) % 6.2f\n',I1);
fprintf (f2, 'cs area of Conductor (sq.mm) % 6.2f\n', a1);
fprintf (f2, 'Axial Slack inHV-Wdg (mm) % 6.2f (desirable: >7)\n', S1kHVax);
fprintf (f2, 'Radial width of Wdg (mm) % 6.2f\n', rwHV);
fprintf (f2, 'Cu.Loss in LV wdg (KW) % 6.3f\n', pcu1);
fprintf (f2, '<-----------5) Performance Calculations--------- >\n');
pcuT = 1.05*(pcu1 + pcu2); ptFL = (pcuT + Pi);
    PF = [1 0.85 0.85 0.85]; LDPU = [1 1 0.75 0.5];
    for i = 1:4;
    pf = PF(i); Ldpu = LDPU(i);
    TL(i) =  Pi + pcuT*Ldpu^2; Opt(i) = Ldpu*KVA*pf;
Inp(i) =  Opt(i) + TL(i); eff(i) = Opt(i)/Inp(i)*100; end;
    Er = pcuT/KVA; Ez = sqrt(Ex^2 + Er^2);
    Reg85 = Er*0.85 + Ex*sqrt(1-0.85^2); RegUPF = Er;
fprintf (f2, 'Efficiency at UPF and Full Load: % 5.2f\n', eff(1));
fprintf (f2, '<-----------6) TANK Design and Weights---------- >\n');
    dL = 140; dB = 180; dH = 500; Dct = 50; Hct = 1000; TRP = 50;
    % Assumptions;
    Lt = 2*D*1e3 + (do1 + dL); bt = (do1 + dB); ht = L*1e3 + (2*hy*1e3 + dH);
Tr = ptFL*1e3/12.5/St; At = pi*Dct*Hct/1e6;
fprintf (f2, 'Tank: Length = % 4.0fmm, Width = % 4.0fmm, Height = % 4.0fmm and
      Volume = % 6.3fm3\n', Lt, bt, ht, Vt);
fprintf (f2, 'Tank : Cooling area = % 6.4fsq.m and Temp-Rise = % 4.0f is
      reduced to 50 deg-C\n', St, Tr);
fprintf (f2, 'Weight: HV-Wdg = % 6.2f + LV-Wdg : = % 6.2f + (Core + Yoke): = %
      6.2f and Total = % 7.1f Kg\n', Wcu1, Wcu2, Wiron, Wtot);
fprintf (f2, 'Kg/KVA = % 6.3f\n', KgPkva);
fprintf (f2, '<----------- End of Program----------->\n');
fclose (f2);
```

<u>Output of MATLAB Program :-</u>

```
800 KVA, 6600, 440 V, 50 Hz, 3 Phase,Delta/Star, Core Type, ON cooled Power
Transformer:
=====================================
<-----1) Design of Magnetic Frame---------------------------- >
Assumed: For 3stepped Core factor(k) =  0.60, Value factor (K) =  0.60
Assumed: Window space factor (kw) =  0.314, Max Core Flux Density (T) =  1.5
Core dia (d) (m)  0.230
CS area of core (sq.m)  0.0317
EMF/turn  10.57
Av-Current density (A/sq.mm) =   2.60
Window Area (sq.m)  0.1235
Length of core (L)(m)  0.5900
Length of Yoke (W)(m)  1.1000
Width X Ht of the yoke (m)  0.2070 and  0.1917
Loss in Core =   1.60W/Kg *  461.04 Kg =  737.67W
Flux Dens in Yoke (T)  1.3043
Loss in Yoke =   1.01W/Kg *  659.00 Kg = 664.73W
Total Iron Loss (KW)  1.473
<-------2) No-Load Current---------------------------->
AT/m: for Core =  150.000 and for Yoke=    109.600
Total-AT: for Core =  265.500 and for Yoke = 241.119
```

```
AT/phase:  168.87
Turns in LV winding     24
Ph-Current in LV wdg (Amp)  1049.7
Magnetizing-Ct (I0 = Iw + jIm)  6.039 =  1.932 + j  5.722 A
 Ratio of IO/I2 (perc)  0.575 (Permissible: 0.5 to 1)
<-----3) Design of LV Winding------------>
Turns (RadialXAxial)  2 X  12
Conductor:  12 Strands in Parallel of W*t (rom*rom)  12 X  3
Strands (RadialXAxial)  4 X  3
CS area of Conductor (sq.rom)  423.36
Radial width of Wdg (rom)  29.00
Mean Length of Turn (m)   0.90
Resistance/phase (m.ohm)  1.0151
Cu.Loss in LV wdg (KW) 3.356
<-----------4) Design of HV Winding------------->
Turns in HV Wdg    624
Ph-Current in HV wdg (Amp)  40.40
Wdg:  12 coils X  48 turns + 2 coils X  24 turns =  624
Conductor(W*t) (mm*mm)  6.0 X  2.5
Axial Slack inHV-Wdg (mm)  23.60 (desirable: >7)
Radial width of Wdg (mm)  34.80
Mean Length of Turn (m)   1.20
Resistance/phase (ohm)  1.0156
Cu.Loss in LV wdg (KW)  4.974
<-----------5) Performance Calculations--------->
Efficiency at UPF and Full Load:  98.74
Efficiency at 0.85 pf and at: 1pu Ld:   98.52,0.75pu Ld:   98.76 and O.SpuLd:
98.94
Max Efficiency =  98.96occuring at Load  328.25KVA
Mean-turn Length =  1.0458m, Axil Length of Wdg =  0.4364m, AT/ph =  25212
Reactance 0.0841pu, Restance 0.0109pu, Impedance = 0.0848pu
Regulation: at FL and 0.85pf =  0.0536pu, at FL and UPF =  0.0109pu
<-----------6) TANK Design and Weights----------->
Tank: Length = 1436mm, Width =  596mm, Height =  1473mm and Volume =  1.260m3
Tank : Cooling area = 5.9853sq.m and Temp-Rise = 137 is reduced to 50 deg-C
Cooling Tubes: Area/Tube = 0.1571sq.m, Required-Area = 14.7650sq.m and No of
Tubes =  94
Weight: HV-Wdg=  97.66 + LV-Wdg : =  80.97 + (Core + Yoke): =  1120.04 and Total
=  1311.7 Kg
Kg/KVA =  1.640
<----------------End of Program------------>
```

7. Conclusion

In this research paper, we had successfully completed the Designing of the Transformer using 'C' language in engineering software MATLAB, a Core type Transformer was required to be designed in the software. So in order to carry out the designing of the transformer, data collection and analytics on transformer designing was done in early stages of this study, and then by using the collected data the simulation program was successfully developed. The results shows that there is reduction of time consumed in calculating the design parameters and will also be useful in designing core type of transformer of any required KVA rating.

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