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COMPUTER AIDED DESIGN OF THE MAGNETIC CIRCUIT OF A 3-PHASE POWER TRANSFORMER

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ABSTRACT

In this paper, a computer program was developed in C++ language to determine the parameters of the magnetic circuit of a three-phase power transformer. A typical case study was used to demonstrate the effectiveness of the program. The program was developed using the mathematical models derived for the parameters to be determined. Apart from being flexible and speedy, the program removed the drudgery involved in the design and demonstrated the usefulness of software as both a teaching and research aid. Tables and graphs obtained from the program showed how the design problems were dealt with and how the parameters of the magnetic circuit were determined.

1.0 INTRODUCTION

The speed of computation, the accuracy of result and the flexibility of computer-based designs make it the best option in the design of transformers. This is because a transformer has so many parameters. Some of the parameters are determined by trial and error selection of values from tables, graph etc, while other parameters are obtained from repetitive computations until the desired values are obtained, Sawhney, (2001). With the computer, the computations are performed rapidly and previous results can be made available to guide in the selection of new values thereby ensuring that the desired values for the parameters are obtained easily and quickly.

Transformer parameters can be grouped into three, those pertaining to the magnetic circuit, the electric circuit and the cooling tank and the design of transformer entails computation of those parameters Best & Crompton Eng, (1981), Bilbir, (1982), Say, (1983), Kosow, (1981). This paper is therefore set to develop computer program for the design of the magnetic circuit of 3-phase power transformers. Other aspects of transformer design - the electric circuit, and the cooling tank design - can be found in Ozuomba et. al,., (2004), Oboma ,(2003),.

2.0 ANALYSIS OF THE MAGNETIC CIRCUIT OF POWER TRANSFORMERS

2.1 Design Specification

Useful specifications for the design are listed in this section. They include, Penders, (1949), Say, (1973), Still, (1970).:

i. Transformer Power rating ,S in KVA
ii. Frequency, f in H_z
iii. Line voltage of the high voltage (H.V) winding, V_{lnhv}
iv. Line voltage of the low voltage (L.V) winding, V_{lnlv}
v. Connection type –star or Delta
vi. Percentage impedance, Z%
vii. Tapping on the H.V winding, T_{p1}, T_{p2}......

2.2 Output Equation of Power Transformer

In order to derive the equation for output power, S of power transformers, the equation for the induced voltage in the windings of the transformer will be derived first. Suppose a coil of N-turns is wound on a core that is carrying a sinusoidal flux Φ, Hughes , (1977), Best & Crompton Eng , (1981), Fitzergerald, (1961).

$$\Phi = \Phi_m \sin 2\pi ft \qquad (2.2.1)$$

where Φ_m is the maximum flux density is Webbers, f is frequency in H_z , t is time in seconds, then the electromagnetic force (emf), e induced in the coil is given by Faraday's law as Oboma, (2003), Hughes, (1977)

$$e = N(d\Phi /dt) \qquad (2.2.2.1)$$

$$e = 2 \pi f \Phi_m N \cos (2 \pi f t) \qquad (2.2.2.2)$$

The maximum emf, E_m is given from Equation (2.2.2.2) as $E_m = 2\pi f\Phi mN$ (2.2.3)

The root mean square (rms) value of E_m is given as

E where $E = E_m / \sqrt{2}$ (2.2.4.1)

$\therefore E = 4.44 f \Phi_m N$ (2.2.4.2)

The maximum flux density, B_m in the core is given as

$B_m = \Phi_m / A_i$ (2.2.5.1)

where A_i is the cross sectional of the iron core area, hence

$\Phi_m = B_m A_i$. (2.2.5.2)

Substituting Φ_m into Equation (2.2.4.2) gives

$E = 4.44 f B_m A_i N$ (2.2.6)

The voltage per turn, V_t is given as E / N, thus from Equation (2.2.6):

$V_t = 4.44 f B_m A_i$ (2.2.7.1)

Thus from Equation (2.2.4.2),

$V_t = 4.44 f \Phi_m$ (2.2.7.2)

Also from Equation (2.2.7.1),

$A_i = V_t / 4.44 f B_m$ (2.2.7.3)

For 3-phase, each core window contains two sections of high voltage (H.V) coils and two sections of low voltage (L.V) coils Oboma, (2003). If N_{phv} and N_{plv} are the number of turns per phase and a_{hv} and a_{lv} are the cross sectional areas of each conductor of the H.V and L.V coils respectively, then the total area of conductors per window is given by .

Total copper area per window =

$2 (N_{phv} a_{hv} + N_{plv} a_{lv})$ (2.2.8)

The current density J is the same in both H.V and L.V coils

Thus $J = I_{plv} / a_{lv}$ (2.2.9.1)

$J = I_{phv} / a_{hv}$ (.2.2.9.2)

$J = I_p / a$ (2.2.9.3)

where I_{phv} and I_{plv} are phase current in the high voltage and low voltage side.

Also, recall that for transformers

$V_{plv} / V_{phv} = N_{lv} / N_{hv} = I_{phv} / I_{plv}$

Thus

$I_{plv} N_{lv} = I_{phv} N_{hv} = I_p N$ (2.2.9.4)

From Equation (2.2.9.3), Equation (2.2.9.2) and Equation (2.2.9.4), $I_{phv} = a_{hv} / J$, $I_{plv} = a_{lv} / J$, $I_p = a / J$, hence substituting I_{phv}, I_{plv} and I_p in Equation (2.2.9.4) gives

$N_{lv} a_{lv} / J = N_{hv} / J = Na / J$ (2.2.10.1)

$\therefore N_{lv} a_{lv} = N_{hv} a_{hv} = Na$ (2.2.10.2)

Substituting for $N_{lv} a_{lv}$ from Equation (2.2.10.2) into Equation (2.2.8) gives

Total copper area per window = $4 N_{hv} a_{hv}$ (2.2.11.1)

Putting in general terms whether it is L.V or H.V value

Total copper area per window = 4 Na (2.2.11.2)

Let k_w stand for window space factor where Penders, (1949),

$$K_w = \frac{\text{total copper section Area per window}}{\text{Total window Area, } A_w} \quad 2.2.13$$

$K_w = 4 aN / A_w$ (.2.2.14)

From Equation (2.2.9.3), $a = I_p / J$, so Equation (2.2.14) becomes

$4 I_p N / J = K_w A_w$ (2.2.15)

$IN = (K_w A_w J) / 4$ (2.2.16)

For 3-phase transformer $S = 3 E I \times 10^{-3}$ (.2.2.17)

Substituting Equation (2.2.6) into Equation (2.2.17) gives

$S = 3(4.44 f B_m A_i N) I \times 10^{-3}$ (2.2.18)

Putting Equation (2.2.16) into Equation (2.2.18) gives

$S = 3(4.44 f B_m A_i)(K_w A_w J) \times 10^{-3}$ (2.2.19)

$= 3.33 f B_m A_i A_w J K_w \times 10^{-3}$ (2.2.20)

For single phase transformers,

$IN = (K_w A_w J) / 2$ (2.2.21)

Thus,

$S_{1\text{-phase}} = 2.22 f B_m A_i A_w J K_w \times 10^{-3}$ (2.2.22)

The power rating (in KVA) can also be expressed in terms of magnetic potential gradient. If D_{sc} is the diameter of the circumscribing circle for the core limb, then, the area of the iron A_i is then given as

$A_i = k_i k_s \pi D_{sc}^2 / 4$ (2.2.23)

where k_s is stacking factor, k_i is iron space factor given in table 2.1

Now, the magnetic potential gradient H_m is given as

$$Hm = \frac{\text{Magnetomotive force (mmf)}}{\text{Height of limb } (H_{lmb})} \quad (2.2.24)$$

Then for a 3-phase transformer, the total magneto motive force, mmf over one limb is given as

$$mmf = 2NI \quad (2.2.25)$$

Putting Equation (2.2.25) into Equation (2.2.24) and solving for NI gives,

$$NI = H_m H_{lmb}/2 \quad (2.2.26)$$

Putting Equation (2.2.26) into Equation (2.2.18) gives

$$S = 3(4.44f\ B_m k_i k_s \pi D_{sc}^2/4)\ (H_m H_{lmb}/2) \times 10^{-3} \quad (2.2.27)$$

$$= (5.23fB_m D_{sc}^2 H_m H_{lmb} k_i k_s) \times 10^{-3} \quad (2.2.28)$$

For single phase transformer,

$$mmf = NI \quad (2.2.29)$$

Thus,

$$S_{1\text{-phase}} = 3.48\ fB_m D_{sc}^2 H_m H_{lmb} k_i k_s) \times 10^{-3} \quad (2.2.30)$$

2.3.1 The Core Dimensions

Power transformer cores are built of thin strips of laminations arranged in a number of steps so as to obtain nearly round cross sectional area so that a better space factor for accommodating iron in the most useful way can be achieved. The number of steps usually chosen are 3,4,5,6,7or 9. Balbir, (1982) .The iron core area, A_i is given in Equation (2.2 23). It is expressed with respect to D_{sc}, k_i and k_s. The value of A_i for various core steps can be obtained from table 2.1

K_i, the iron space factor is there because of the use of steps of iron instead of one solid round section of iron core. K_s is due to paper or vanish insulation between the laminations of the core,

$$D_{sc} = \sqrt{4}\ A_i/\pi k_i k_s \ldots \quad (2.3.1)$$

K_s=0.92 for all steps of core. The maximum length of the core limb L_{mc} is given in table 1 for various core steps. It is expressed with respect to D_{sc} in the form

$$L_{mc} = k\ (D_{sc}) \quad (2.3.2)$$

where k is the factor relating L_{mc} to D_{sc}. The value of k is given in table 2.1 for the various core steps

2.3.2 Core yoke dimensions

The flux in the core limb is the same as the flux in the yoke Bilbir , (1981), Oboma, (2003). Hence, from Equation (2.3.2)

$$B_{lmb} A_{lmb} = B_{yk} A_{yk} \quad (2.3.3)$$

where B_{lmb} and B_{yk} are the flux density of the limb and yoke, A_{lmb} and A_{yk} are the cross sectional area of the limb and yoke respectively. Note that

$$B_{lmb} = B_m \ldots \quad (2.3.4.1)$$

and

$$A_{lmb} = A_i, \quad (2.3.4.2)$$

Then, from Equation (2.3.3)

$$A_{yk} = A_i B_m / B_{yk} \quad (2.3.5)$$

In practice $B_{yk} \leq B_m$ (2.3.6)

Empirical values for B_{yk} can be chosen from the relation

$$1 \leq B_m / B_{yk} \leq 1.25 \quad (2.3.7)$$

Put another way $B_m / 1.25 \leq B_{yk} \leq 1$ (2.3.8)

The diameter of the circumscribing circle for the core yoke is given as in Equation (2.3.1)

$$D_{syk} = \sqrt{(4\ A_{yk} / \pi k_i k_s)} \quad (2.3.9)$$

Similarly, the maximum length of the yoke, L_{my} is given as in Equation (2.3.2)

$$L_{my} = K(Dsyk) \quad (2.3.10)$$

where k, k_i , and k_s are the same as the ones used for the core in Equation (2.3.1) and (2.3.2)

2.3.3 The Core Window Dimensions

From Equation (2.2.20), the core window area, A_w is given as

$$A_w = S / ((3.33\ fB_m A_i J k_w) \times 10^{-3} \quad (2.3.11)$$

Table 2.2 gives the window space factor, k_w.. With k_w selected from table 2.2, and the value of current density, J chosen, A_w can be computed from Equation (2.3.11).In practice, the ratio of the window Height, H_w to the window width, W_w is between 2 and 4. If Υ_{hw} represent the ratio of H_w to W_w then:

$$\Upsilon_{hw}=H_w/W_w \qquad (2.3.12)$$

It means from the statement above that

$$2 \leq \Upsilon_{hw} \leq 4 \qquad (2.3.13)$$

However, values of Υ_{hw} beyond this range can be used. From Equation (2.3.12)

$$H_w = \Upsilon_{hw} W_w \qquad (2.3.14)$$

Now $$A_w = H_w W_w \qquad (2.3.15)$$

Thus $$A_w = \Upsilon_{hw} W_w^2 \qquad (2.3.16)$$

Hence $$W_w = \sqrt{(A_w/\Upsilon_{hw})} \qquad (2.3.17)$$

2.3.4 The Overall Core Frame Dimension

Overall core frame height, H is given as

$$H = H_w + 2L_{my} \qquad (2.3.18)$$

The center-to-center distance, D_{cc} is given as:

$$D_{cc} = W_w + D_{sc} \qquad (2.3.19)$$

The overall core width

$$W = 2D_{cc} + L_{mc} \qquad (2.3.20)$$

2.4 Weight Of The Core

The volume of iron core can be found from the product $A_i.L_{mf}$ where L_{mf} is the mean flux path including the core limb and yokes. For single phase transformers

$$L_{mf} = 2(W_w + D_{lmb}) = 2(H_w + W_{lmb}) \qquad (2.4.1)$$

For 3-phase transformers

$$L_{mf} = 2(2W_w + 2D_{lmb}) = 3(H_w + W_{lmb}) \qquad (2.4.2)$$

where $D_{lmb} = D_{sc}$ is the diameter of the circumscribing circle for the core limb cross section, H_w is the window height. The volume of iron V_i is given as

$$V_i = A_i.L_{mf} \qquad 2.4.3)$$

If the density of the iron core in Cm^3 / kg is P_{ic}, then weight of iron, W_i is given as

$$W_i = V_i P_{ic} \qquad (.2.4.4)$$

2.5 Weight Of The Copper

If E_{phv} and E_{plv} are the phase voltages of the H.V and L.V winding respectively, then

$$N_{hv} = E_{phv} / V_t \qquad (2.5.1)$$

$$N_{lv} = E_{plv} / V_t \qquad (2.5.2)$$

Note, for star connection, phase voltage is given as (line voltage/ √3).

To calculate the weight of copper, an approximate value can be obtained from the conductor cross sectional area and the mean length of turns, L_{mt} . Assuming that the window space is completely filled with oil, we can allocate half of the window space to coils on each core limb. The mean diameter of the coil D_{mt} is therefore given as Bilbir, (1982) .

$$D_{mt} = D_{lmb} + W_w/2 \qquad (2.5.3)$$

Since $D_{lmb} = D_{sc}$

$$\therefore D_{mt} = D_{sc} + W_w/2 \qquad (2.5.4)$$

$$\therefore L_{mt} = \pi D_{mt} \qquad (2.5.5)$$

The volume of copper V_{cp} is given as

$$V_{cp} = K_w L_{mt} (W_w/2) H_w \qquad (2.5.6)$$

where K_w is the window space factor . If ρ_{cp} is the density of copper, then weight of copper W_{cp} is given as

$$W_{cp} = V_{cp}\rho_{cp} \qquad (2.5.7)$$

2.5.2.1 Empirical Formula for Voltage per Turn V_t

In the design of a transformer, the value of voltage per turn, V_t is often needed to be chosen or calculated quite fairly from the available parameters. The value of V_t so chosen affects the size and weight of the transformer as well as other performance characteristics of the transformer. Experts have proffered some empirical formula for V_t . Two of the formula will be discussed here.

Suppose we define

r = (Magnetic Loading) / Electric Loading) (2.5.8.1)

where Magnetic Loading $= \Phi_m$ (2.5.8.2)

Electric Loading = IN (2.5.8.3)

$$\therefore r = \Phi_m / IN \qquad (2.5.9)$$

$IN = \Phi_m / r$ (2.5.10)

Now , from Equation (2.2.7.2)

$V_t = 4.44\ \Phi_m$ (2.5.11)

Also, from Equation (2.2.17) $S = 3EI \times 10^{-3}$ and $E = Vt\ N$, hence

$S = (4.44\ \Phi_m\ NI) \times 10^{-3}$ (2.5.12)

Putting Equation (2.5.10) into Equation (2.5.12) gives $S = 4.44\ f(\Phi_m^2/r) \times 10^{-3}$ (2.5.13)

$\therefore\ \Phi_m = \sqrt{((S.r)/((4.44f) \times 10^{-3}))}$ (2.5.14)

Putting Φ_m from Eq2.5.14 into Equation (2.5.11) gives

$V_t = (4.44f)(\sqrt{((S.r)/((4.44f) \times 10^{-3}))})$ (2.5.15.1)

$\therefore\ V_t = \sqrt{((4.44f)(S.r) \times 10^{-3})}$ (2.5.15.2)

If we define $C = \sqrt{((4.44f)(r) \times 10^{-3})}$ (2.5.16)

$\therefore\ V_t = C\sqrt{S}$ (2.5.17)

where S is the power rating in KVA . From Equation (2.5.17) , $C = V_t/\sqrt{S}$ (2.5.18)

2.5.2.2 Significance of C

Form Equation (2.5.16), C is proportional to r. Also, from Equation (2.5.9) r is proportional to Φ_m. A s such , C is proportional to $\Phi_m$and hence an increase in C will result to increase Φ_m, if other variables remain constant.

Now, $\Phi_m = B_m A_i$. If B_m is kept constant increasing Φ_m will result to increase in A_i , which is the amount of iron used in the transformer . On the other hand, N , the number of turns indicate the amount of copper used in the transformer. For any given E, ($E = 4.44\ f\ N\ \Phi_m$) and for a particular S, if Φ_m is increased , N will decrease , if Φ_m is decreased , N will increase. So, it will be observed that increasing the value of C will increase the amount of iron (A_i) used and decrease N , the number of turns of copper. On the other hand decreasing the value of C will decrease the amount of iron (A_i) used and increase N. Therefore, C is a constant that indicates the amount of iron, A_i used and the number o turns, N of the transformer. Table 2.3 gives the average values that are usually used in practice for C Bilbir, (1982)

2.5.3 Second Empirical Formula For V_t

Another empirical formula for V_t is given as Bilbir, (1982)

$V_t = (1/40)\sqrt{((S \times 1000) / \text{Number of Legs})}$ (2.5.19)

where S is in KVA. The number of legs for 3-phae core type is 3 while it is 2 for single phase transformers. Equation (2.5.4) or Equation (2.5.19) can be used to obtain a fairly accurate value for V_t

3.0 ALGORITHM FOR DESIGNING THE MAGNETIC CIRCUIT OF 3-PHASE POWER TRANSFORMER

3.1 Design Specifications

Obtain the values of the following parameters from the given design specifications

3.1.1 Transformer Power rating ,S in KVA

3.1.2 Frequency, f in H_z

3.1.3 Line voltage of the high voltage (H.V) winding, V_{lnhv}

3.1.4 Line voltage of the low voltage (L.V) winding, V_{lnlv}

3.1.5 Connection type –star or Delta

3.1.6 Percentage impedance, Z%

3.1.7 Tapping on the H.V winding, T_{p1}, T_{p2}.......

3.2 Core Parameters

3.2.1 Compute volt per turn, V_t from Eq2.5 .17 or Equation (2.5.19)

3.2.2 Compute cross sectional area of core, A_i from Equation (2.2.7.3)

3.2.3 Select window space factor from Table 2.2

3.2.4 Choose value for current density, J

3.2.5 Compute window area A_w from Equation (2.3.11)

3.2.6 Select suitable ration for window height to window width from Equation (2.3.13)

3.2.7 Compute window area, W_w from Equation (2.3.17)

3.2.8 Compute window height, H_w from Equation (2.3.14)

3.2.9 Choose number of steps for the Core

3.2.10 Choose iron space factor, K_i from Table 2.1

3.2.11 Choose stacking factor $K_s = 0.92$

3.2.12 Choose diameter of circumscribing circle of Core limb, D_{sc}

3.2.13 Select K from Table 2.1 for the chosen number of steps in core

3.2.14 Compute maximum length of core, L_{mc} from Equation (2.3.2)

3.2.15 Choose flux density of the yoke, B_{yk} form Equation (2.3.7)

3.2.16 Compute diameter of circumscribing circle of yoke, D_{syk} form Equation (2.3.9)

3.2.17 Compute maximum length of yoke L_{my} from Equation (2.3.10)

3.2.18 Compute center-to center distance of limb, D_{cc} from Equation (3.3.19)

3.2.19 Compute overall core width, W from Equation (2.3.20)

3.2.20 Compute overall core height, H from Equation (2.3.18)

3.2.21 Compute mean length of flux path, L_{mf} from Equation (2.4.2)

3.2.22 Compute the volume of iron, V_i from Equation (2.4.3)

3.2.23 Compute the weight of iron, W_i from Equation (2.4.4)
3.2.24 Compute number of turns in H.V winding, N_{hv} from Equation (2.5.1)
3.2.25 Compute number of turns in L.V winding, N_{lv} from Equation (2.5.2)
3.2.26 Compute mean diameter of the coil, D_{mt} from Equation (2.5.4)
3.2.27 Compute mean diameter length of turn, L_{mt} from E quation (2.5.5)
3.2.28 Compute volume of copper, V_{cp} from Equation (2.5.6)
3.2.29 Compute weight of copper W_{cp} From Equation (2.5.7)

3.4 The Computer Program

The algorithm of section 3.1 is developed into C++ program. The program can be used to computer the values of the parameters outlined in the algorithm or in the flowchart.

4.0 SAMPLE DESIGN PROBLEM

Design a 800KVA 3-phase 50Hz, 220KV/11KV, Delta/Delta connected power transformer, with construction type: core, cooling type OFAE, temperature rise of coil 50°C, percentage impedance 11.50%, the transformer is provided with tapings of ±5% on the High voltage winding and has a total loss not more than 50Kw.

4.1 Results For The Sample Design

The C++ program was used to carry out the sample design. The program accepts the design specifications as input and computes the values of the parameters of the electric circuit. The screenshots of sample results are given below.

4.2 Discussion Of Result

(i) From Fig 4.1 and Table 4.1 , the volt per turn is directly proportional to C for a constant power rating, S. Hence, the choice of C determines the volts per turn for any given S.

(ii) From Table 4.1 , Fig 4.2 and Fig 4.3 , the number of turns, N , and the weight of copper, W, decreases as C and V_t increase for constant current density ,J, conductor area , the L.V and H.V currents .

From table 4.1, Fig 4.2, and Fig 4.3, A_i, and W_i increase as C and V_t increase for constant B_m hence, increasing the quantity of iron used while decreasing the quantity of copper used.

5.0 CONCLUSION

In this paper, a program was developed for the design of the magnetic circuit of 3-phase power transformer. Firstly, mathematical models were developed for all the parameters to be calculated. Secondly, the algorithm for the design was developed. Then sample design problem was used to demonstrate the effectiveness of the program. The sets of results obtained from the sample problem demonstrated how easy and quickly the desired values for the parameters could be obtained when the program was used for the design.

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TABLE 2.1 IRON SPACE FACTOR (K_i) AND K , THE RATIO OF THE DIAMETER OF THE CIRCUMSCRIBING CIRCLE TO THE MAXIMUM CORE LIMB LENGTH FOR VARIOUS CORE STEPS

		Core Diameter (mm)	Number of Core Steps	Iron Space Factor (K_1)	$K = L_{md}/D_{sc}$
Single Frame Without Duct	Duct	< 100	1	0.64	0.71
		< 100	2	0.79	0.85
		< 100	3	0.84	0.90
		< 100	4	0.87	0.93
		100 – 250	5	0.89	0.95
		250 – 300	6	0.89	0.96
Double Framed	Longitudinal Duct	350 – 750	6 – 8	0.86	0.97
		550 – 1000	7 – 10	0.98	0.98

Table 2.2 WINDOW SPACE FACTOR, K_W Balbir, (1982)

KVA	3KV	10KV	30KV	100KV
100	0.28	0.20	0.14	0.13
800	0.37	0.27	0.20	0.15
2000	0.40	0.31	0.23	0.16
≥ 10000	0.45	0.37	0.28	0.21

Table 2.3 EMPIRICAL AVERAGE VALUES FOR THE FACTOR C

Transformer Type	Range OF Values For C
Core Type Distribution Transformer	0.35 to 0.45
Core Type Power Transformer	0.555 to 0.65
Shell Type Transformer	1.0 to 1.25

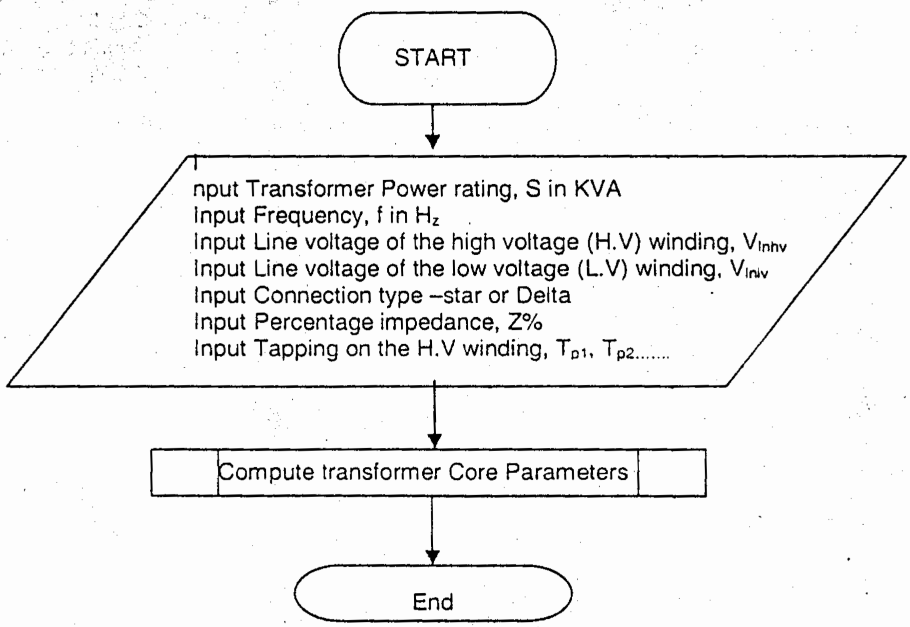

Fig 3.1: Flowchart for the Design of the magnetic circuit of 3-phase power transformer

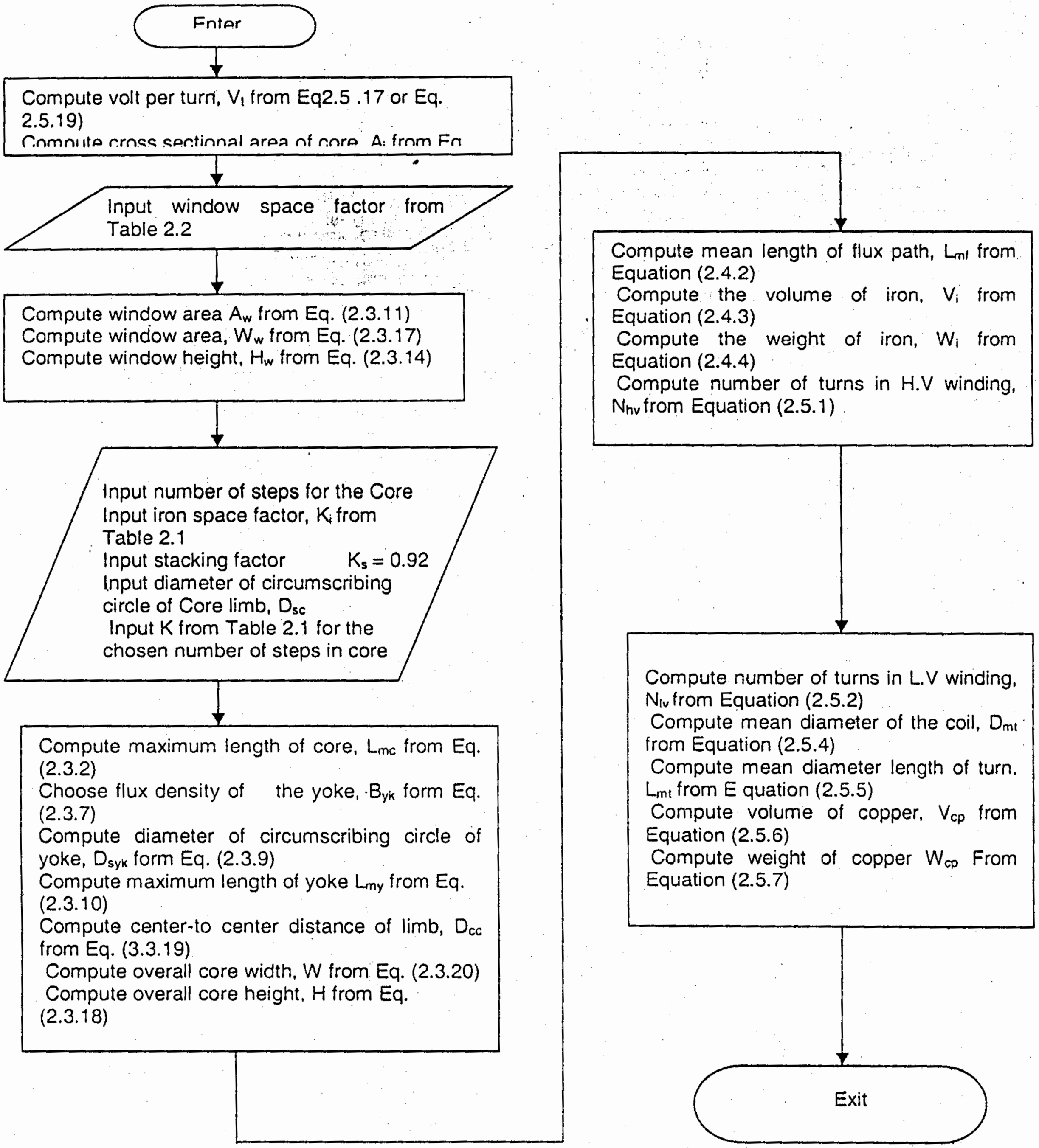

Fig 3.2 : Flowchart for the Computation of the transformer Core Parameters of 3-phase power transformer

C:\BC45\BIN\PWR TANS.EXE

TRANSFORMER DESIGN INPUT SPECIFICATIONS

Power Rating in KVA	= 8000.000
Frequency in Hz	= 50.000
High Voltage Rating in KV	= 220.000
Low Voltage Rating in KV	= 11.000
Cooling Type	= OFAF
Oil Temperature in Centigrade	= 50.000
Construction Type	= core
Connection Type	= Delta/Delta
Percentage Impedance	= 11.500
Tapping on High Voltage Winding(%)	= %.3f

THE PARAMETERS FOR CORE DESIGN

Volt Per Turn in Volts	40.000
Net Area of Iron in Square milimeter	112612.609
Gross Area of Core in Square Milimeter	117617.531
Diameter of Circumscribing Circle in Milimeter	430.000
Length of Lamination in Milimeters	400.000
Iron Factor	0.880
stacking Factor	0.920
Maximum Flux Density	1.600000E-06

Program running

Start 6:54 AM

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THE PARAMETERS FOR CORE WINDOW DESIGN

Window Factor	0.288
Maximum Current Density in Amp Per Square milimeter	6000000.000
Window Height in Milineter	600.000
Window Width in Milimeter	300.000
Area of Window in Square Milimeters	154400.000
Distance Between Core Centres in Milimeters	770.000

THE PARAMETERS FOR YOKE DESIGN

Gross Area of Yoke	135135.125
Depth of Yoke	460.910
Heiight of Yoke	293.192
Flux density of Yoke	0.0000013

THE PARAMETERS FOR OVERALL DIMENSION OF CORE FRAME

Overall Height of Frame in Milimeter	1186.383
Overall Width of Frame in Milimeter	2000.910
Overall Depth of Frame in Milimeter	460.910

Program running

Start 7:03 AM

TABLE 4.1: VOLT/TURN, CROSS SECTIONAL AREA OF IRON, THE NO. OF TURN OF THE LV WINDING, WEIGHT OF COPPER (KG) AND WEIGHT OF IRON (KG)

Constant , C	Volt/Turn, V_t	Cross Sectional Area Of Iron $(mm^2)*10^{-2}$	No. Of Turns Of The L.V Winding	Weight Of Copper (Kg)	Weight Of Iron (kg)
0.335	30.000	870.841	367	2339.3	5110.6
0.501	45.000	1288.132	244	1611.1	7513.6
0.671	60.000	1720.053	183	1287.7	10942.3
0.839	75.000	2139.888	147	1097.2	13080.3
0.848	75.865	2139.884	145	1083.3	13265.4
1.006	90.000	2605.524	122	978.2	16833.2

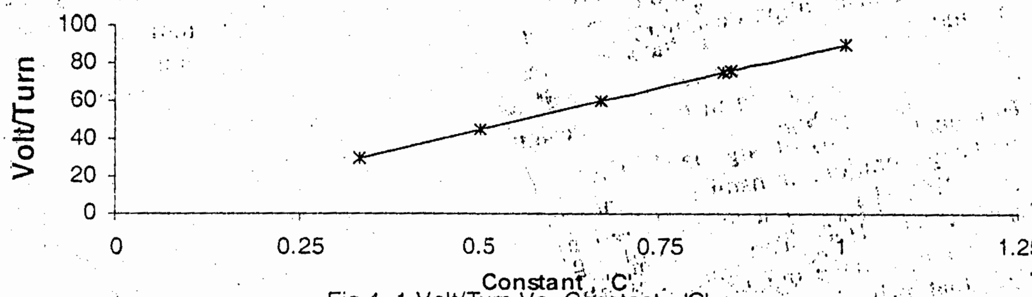

Fig 4. 1 Volt/Turn Vs. Constant , 'C'