ELECTRICAL POWER

"DESIGN OF POWER TRANSFORMERS USING DIGITAL COMPUTERS"

A Thesis Submitted

to

The Faculty of Engineering
Ain-Shams University
Cairo, Egypt

By

Eng. ELSAYED MOHAMED MAHMOUD ELSONBATY
B.Sc. Electrical Engineering, June 1962
Diploma of Higher Studies in Electrical
Engineering, June 1967

For

The Degree of Master of Science
In
Electrical Engineering
Supervised by

Prof. Dr. A.M. EL-ARABATY & Dr. EZZAT A.A. MANSOUR

1972

لجنة فحص ومناقشة الرسالة

		التوقيع
دكتور / محمود صبري ابوحسين	استاذ هندسة القوى الكهربائيه هندسة القاهره	محمود صبري ابوحسين ٧٢/٧/٥
دكتور /على كامل الخراشى	استاذ مساعد بهندسة عين شمس	على الخراشى ٧٢/٧/٥
دكتور / احمد محمود الصرياقى	استاذ محطات القوى والشبكات بهندسة عين شمس والمشرف على الرسالة	٧٢/٧/٥

بسم الله الرحمن الرحيم

SUMMARY

This thesis presents a design of power transformers for ratings from 500 K.V.A to 2000 K.V.A., medium voltages up to 22 kV, using digital computers.

By applying the theoretical study on the actual products present, a design for an 1000 K.V.A. transformer manufactured by EL NASR COMPANY FOR THE MANUFACTURE OF TRANSFORMERS AND ELECTRICAL PRODUCTS " ELMACO" in A.R.E., has been made, thus rendering the research more useful. Design particulars, such as customer requirements, operating conditions, standard specifications, iron losses, copper losses, reactance voltage drop, type of cooling, temperature limits, and short circuit duration for automatic circuit breaker choice, are taken into account.

The thesis includes introduction which gives a general description of power transformers and its basic elements (iron core, windings, tap-changer, cooling tubes, oil, expansion tank, dehydrating breather) and also gives a brief look at digital computers (operation, functional organization, Fortran language, Flow chart, ICL 1905E digital computer).

It contains historical review of important papers which had been done in the field of design of power transformers using digital computers and general observations concerning these papers.

Previous work in programming for design of transformers of small ratings taking into account " Deng " paper by Oerlikon Engineering Company in Switzerland together with modifications to suit local designs is included.

It also contains the means by which a program for the design of such transformers can be made, in such a way so as to give the necessary results with a large saving of effort and time. This program, prepared and executed using the " ICL 1905E " of the scientific computation center of Cairo University, has been applied to " ELMACO " transformers for ratings 500, 800, 1000, 1250, 1500 KVA, the latter being the maximum transformer rating manufactured by the Company.

Tables, containing output results of the above mentioned program for transformers up to 1500 KVA together with performance curves and technical comments, are included.

Extension of program possibilities for future developments in the manufacturing of locally produced power transformers of higher ratings are made. The program has been extended to include a rating of 2000 KVA. The program gives details of design and execution of one transformer in 26 seconds and for complete line production of Six transformers with different ratings, the required informations can be obtained in 41 seconds.

We would like to thank Messrs, EL NASR COMPANY FOR THE MANUFACTURE OF TRANSFORMERS AND ELECTRICAL PRODUCTS " ELMACO " for their Co-operation during this work.

Thanks are also due to the Scientific Computation Center, Cairo University , for providing the computer facilities during the progress of this work.

ACKNOWLEDGEMENTS

Theauther wishes to express his deep gratitude to Professor Dr. A.M.EL-ARABATY, Professor of Electrical Power Stations and Networks, Electrical Department, Faculty of Engineering, Ain-Shams University , for his deep interest and adoption of this research. He also thanks him for his suggestions to make the research more useful and applicable to industry.

The author wishes to express his thanks to Dr. EL-SADEK A.KANDIL, Prof. in the Electrical Engineering Department, Ain-Shams University for his kind help and encouragement during this work.

He also wishes to express his thanks to Dr.EZZAT A.A.MANSOUR for suggesting the topic of the research, for his invaluable encouragement, and guidance during all stages of this work, and in the preparation of the thesis, until it come out in such a form.

The author is also indebted to Professor Dr. SAAD EL-DIN YOUSSEF, head of the Electrical Engineering Department, Ain-Shams University for his kind help during this work.

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List of Principal Symbols

The following are the symbols in general use throughout this thesis, unless otherwise stated, keeping in mind that the second symbol if found, referes to the digital computation work.

Qx	=	rated output in KVA
N	=	number of phases
F	=	frequency in cycles/second
V1	=	high voltage in volt/phase
V2	=	low voltage in volt/phase
Ur,URX	=	percentage resistance
Ux,Uxx	=	percentage reactance
Uk,UKX	=	percentage impedance
COSPH	=	power factor
SINPH	=	reactive power factor
VT1	=	starting volt/ turn.
V/T,VTX	=	final volt/turn
Q1	=	designed output in KVA
I1	=	high tension current, amp.
Δ1,CD1X	=	high tension current density, amp/mm^2
Δ2,CD2X	=	low tension current density,amp/mm^2
A1,AC1X	=	cross-sectional area of H.T.wdg., mm^2
A2,AC2X	=	cross-sectional area of L.T.wdg., mm^2
WL1X	=	height of copper cross-section of H.T.wdg.,mm
BC1X	=	breadth of copper cross-section of H.T.wdg,mm

Wlo,TLX	=	length of high tension winding before drying , mm
TLR	=	length of high tension winding after drying , mm
m5, M5C	=	exact height of higher support of H.T. wdg., mm
wlu,TLX2	=	length of low tension winding before drying, mm
TLR2	=	length of low tension winding after drying , mm
m3,M3C	=	exact height of higher support of L.T. wdg., mm
TLX,TLX1	=	maximum length of winding, mm
who,TBIX	=	width of high tension winding , mm
whu,TB2X	=	width of low tension winding, mm
DFe	=	effective diameter of core, mm
N1,W1	=	number of turns of high tension winding
N2,W2	=	number of turns of low tension winding
Bl,BLX	=	flux density in limb, gauss
By ,BYX	=	Flux density in yoke , gauss
SLX	=	specific iron loss in limb, watt/kg
SYX	=	specific iron loss in yoke, watt/kg
io, IOX	=	percentage no load current
PD	=	designed iron losses, watt
AL	=	area of limb, cm^2
Ay	=	area of yoke, cm^2
Gl	=	weight of limb, kg

Gy	=	weight of yoke, kg
P1(I)	=	guaranteed iron losses, watt
D1	=	iner diameter of low tension winding,mm
D2	=	inner diameter of high tension winding,mm
Lm1	=	mean length of high tension turn, m
Lm2	=	mean length of low tension turn, m
G1	=	weight of copper of H.T.wdg., kg
G2	=	weight of copper of L.T.wdg, kg
R1	=	resistance of high tension winding, ohm
R1	=	resistance of high tension winding, ohm
R2	=	resistance of low tension winding, ohm
Dm	=	mean diameter , mm
Z10	=	number of double coils
TS	=	short circuit time
W1,W3,W5,W7,W9	=	corresponding number of high voltage turns at zero, +2.5,+5,-2.5,-5 percentage of tapping
V1,V3,V5,V7,V9	=	corresponding high voltages at zero, +2.5,+ 5,-2.5,-5 percentage of tapping.
W11	=	number of turns with additional insulation
W12	=	number of turns with normal insulation
PC1	=	high tension copper losses, Watt
PC2	=	low tension copper losses, Watt
PCT	=	total copper losses, Watt
PCT 75	=	total copper losses at 75°C , Watt
SOX1	=	factor for stray losses in percentage of PCT, Watt
PS	=	stray losses, Watt

PL	=	load losses , Watt
PC (I)	=	guaranteed load losses, watt
S1x	=	surface area /total losses in H.T . wdg.,cm^2 /Watt.
S2X	=	surface area / total losses in L.T. wdg.,cm^2/ Watt
THAL PK1	=	temperature rise of copper in H.T.wdg.,°C
THAL PK2	=	temperature rise of copper in L.T.wdg.,°C
TR	=	mean temperature rise of oil, °C
TOMX	=	temperature rise of oil at the tap,°C
ZETAX1	=	factor for circulation height/length of winding
ETAX1	=	factor for cooling system height
GAMMAX1	=	losses/area for cooling system, Watt/m^2
V,W	=	permissible losses of tank, watt
PT1	=	total designed losses, watt
DELTAX	=	factor for maximum oil temperature
TOM1	=	maximum temperature of oil upper limit,°C
HR,HRX	=	height of cooling system, m
a,AX2	=	distance between top of tank and end of winding, mm
NTX	=	number of tubes in one cooling system
NCX	=	number of cooling system
FH	=	area of cooling system in horizontal direction , m^2
F K	=	area of cooling system in perpendicular direction , m^2