Computer Aided Design of DC Machines

PROJECT REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
BACHELOR OF ENGINEERING IN
ELECTRICAL AND ELECTRONICS ENGINEERING
OF BHARATHIAR UNIVERSITY, COIMBATORE

BY

A. Bharathan
A. Paul Raj
S. Velmurugan

1992-1993

UNDER THE GUIDANCE OF

Dr. K. A. Palaniswamy,
B.E., M.Sc.(Engg), Ph.D., M I.S.T.E., C.Eng.(I), F.I.E.

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE - 641 006

Department of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore - 641 006

Certificate

Name A. Bharathan A. Paulraj. S. Velmurugan Roll No. ~~89 EEE 04~~, ~~89 EEE 84~~, ~~89 EEE 32~~

Register No. ____________

This is the bonafide Record of the Project Work titled

"COMPUTER AIDED DESIGN OF DC MACHINES"

done by

Mr. A. Bharathan, A. Paulraj, S. Velmurugan

in partial fulfilments of the requirements for the award of the Degree of

Bachelor of Engineering in Electrical and Electronics Engineering

Branch of Bharathiar University, Coimbatore

during the academic year 1992-'93.

Station : Coimbatore

Date :

Dr. K. A. PALANISWAMY, B.E.,M.Sc. (Engg).Ph.D.
M.I.S.T.E.,C.Engg (I).,F.I.E.,
Professor and Head
Department of Electrical and Electronics Engineering,
Kumaraguru College of Technology.
Coimbatore 641 006

Guide

Dr. K. A. PALANISWAMY, B.E.,M.Sc. (Engg).Ph.D.
M.I.S.T.E.,C.Engg (I).,F.I.E.,
Professor and Head
Department of Electrical and Electronics Engineering,
Kumaraguru College of Technology.
Coimbatore 641 006

Head of the Department

Submitted for the University Examination held on ____________

Internal Examiner

External Examiner

Dedicated to

Our Beloved Parents

Acknowledgement

ACKNOWLEDGEMENT

We are greatly indebted and we express our profound
gratitude to our guide **Dr.K.A. PALANISWAMY, B.E.,**
M.Sc(Engg), Ph.D., M.I.S.T.E., C.Eng(I), F.I.E., Professor
and Head of the department of Electrical and Electronics
Engineering who has given us invaluable help and support to
complete this project sucessfully.

We would like to express our sincere thanks to Major
T.S.RAMAMURTHY B.E., M.I.S.T.E., principal of our college
for his encouragement.

We express our heartly thanks to **Dr. S. PALANICHAMY,**
M/s Mighty electronics equipments corporation,coimbatore for
his constant interest and help on the sucessfull completion
of this project.

We thank prof **P. SHANMUGAM. MSc. (Engg), M.S SMIEEE,**
MISTE professor and Head of the Department computer science
& Engg. for providing us the computer facilities for the
development of the software. We also thank prof. **CHRISTIAN**
PAUL , M.sc.,(Engg), M.I.S.T.E. for his keen interest in
this project.

Synopsis

SYNOPSIS

This project presents an efficient, simple and flexible software for the design of medium and large size Dc machines. The software package is developed in Turbo-c which can be easily remodified. The software gives the accurate results with the constraints of efficiency and economy. The Design constraints and Design procesure are incorporated in the software.

More over this package gives design data and instructions to the user. The model design and source program listing are also presented.

Contents

CONTENTS

Nomenclature

NOMENCLATURE

			UNITS
a	-	No of parallel paths.	
ac	-	Ampere conductors/meter. (Electrical loading)	
Atp	-	Armature ampere turns	AT
Ati	-	Interpole ampere turns	AT
Ab	-	Area of brush	M^2
Bave	-	Average flux density	Tesla
Bmax	-	Maximum flux density	Tesla
CO	-	Output coefficient	
Cl	-	Leakage coefficient	
D	-	Diameter of armature core	M
DC	-	Diameter of commutator	M
Df	-	Depth of field winding	M
Ds	-	Depth of slot	M
D shaft	-	Diameter of shaft	M
E	-	Emf induced	volts
Eff	-	Efficiency at full load	%
f	-	Frequency of flux reversals	H_z
H_s	-	Height of slot	M
Ia	-	Current in armature	A
If	-	Field current	A
Il	-	Line current	A
Iarm	-	Armature voltage drop	volts

loa	-	Armature Cu loss	Walts
losc	-	Iron loss in core	"
lost	-	Iron loss in teeth	"
lofw	-	Friction & Windage losses	"
losst	-	Total losses.	
L	-	Length of armature	M
Li	-	Nett length of iron	M
Lmts	-	Length of mean turn	
Lc	-	Length of commutator	M
Lb	-	Length of brush	M
Lip	-	Length of interpole	M
Ldi	-	Length of under interpole	M
M	-	Product of PA & nr	KW/min.
Nb	-	No of brushes	
Nvd	-	No of ventilating ducts	
PA	-	Power developed in armature	KW
P	-	No of poles	
Pc	-	Commutator pitch	
Pw	-	Winding pitch	
Ra	-	Resistance of armature conductor	ohms
S	-	No of slotss	
sp	-	Slot pitch	
Tou	-	Ratio of pole arc to pole pitch	
Ti	-	Interpole turns	
V	-	Peripheral velocity of armature	M/S
Vc	-	Peripheral velocity of commutator	M/S

Introduction

CHAPTER I

INTRODUCTION

The computer aided design deals with the exact dimensions of the machine while computer aided design and Drafting gives the diemnsions as well as the drawings. The Design process of single machine may be divided into three major parts.

i) Electromagnetic Design

ii) Mechanical Design

iii) Thermal Design.

It is clear that the design of electrical machines is an iterative process where in the assumed data may have to be varied many times to arrive at the desired design. The evoluation of design to meet specified optimum criteria is a matter of long and tedious iterations and this is the biggest factor which has led to the widespread use of digital computers for the design of electrical machines.

1.1 DIFFERENT APPROACHES OF CAD:

ANALYSIS METHED

This method is depiced in Fig 1. In this method the choice of dimensions, materials, and types of construction are made by the designer and these are presented to the computer as input data. The designer examines the output of computer and makes another choice of input,if necessary and the performance is recalculated. this procedure is repeated till the performance requirements are satisfied.

The analysis method of design is an excellent starting point for one beginning with the use of application of digital computers for the design of electrical machines and in fact most of the designers initially started off with this method.

1.1.2 SYNTHESIS METHOD

This method of design implies designing a machine which satisfies a set of specifications of performance indices. given a set of performance indices an infinite no of designs can be produced to satisfy them. Therefore the synthesis design should be such that it produces an optimum design because the object of any good synthesis program is just that only.

The greatest advantage of this method is saving in time. The flow chart for this method is given in in Fig 1.2

1.1.3 HYBRID METHOD:

This method incorporates both the analysis and the synthesis methods in the program. Since the synthesis method involve higher cost, the major part of the program is based upon analysis with a limited portion of the program being based upon synthesis.

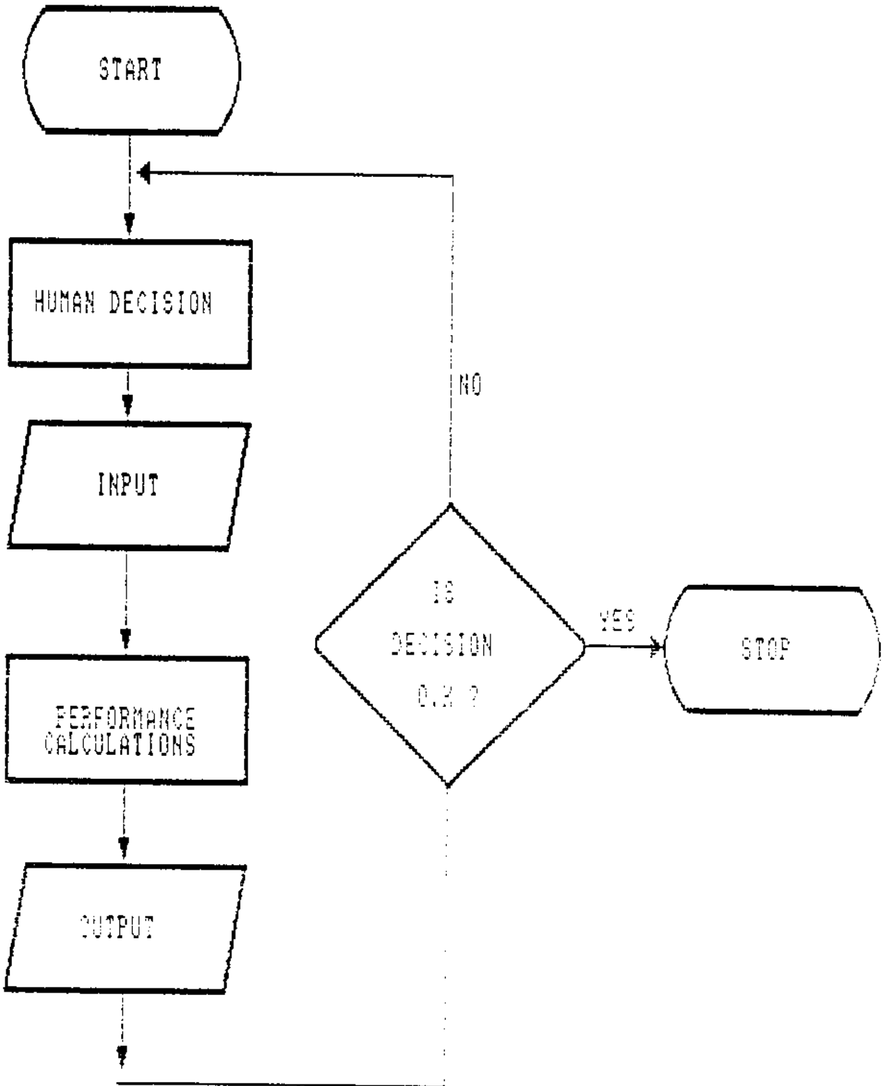
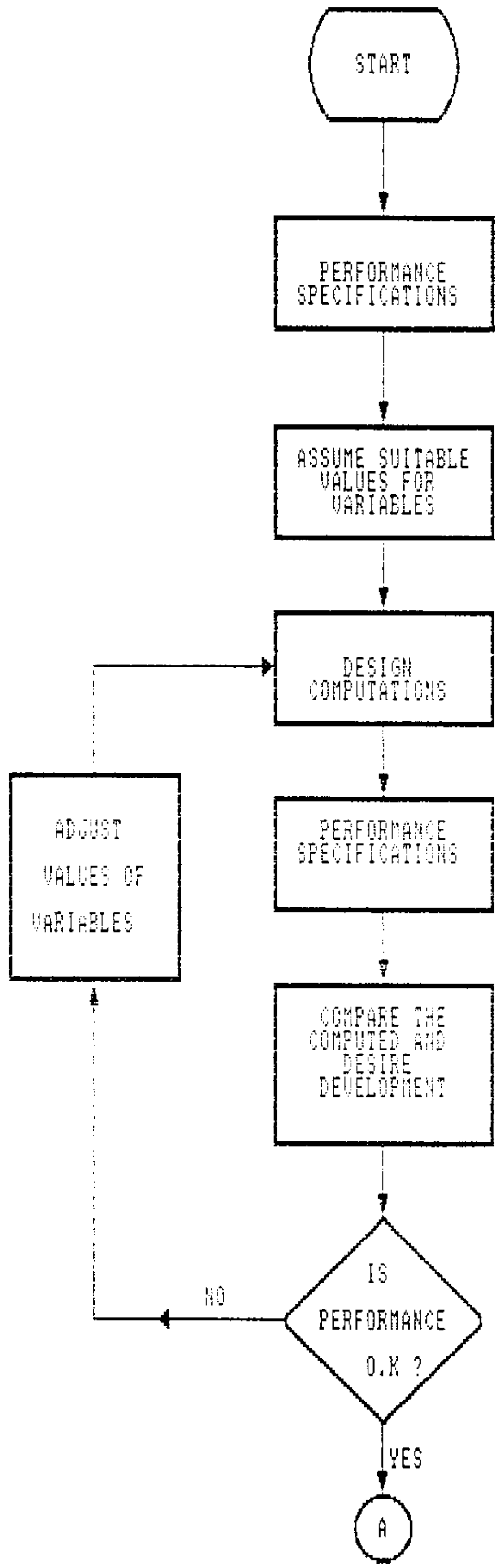


FIGURE 1.1 FLOW CHART FOR ANALYSIS METHOD.


START
PERFORMANCE SPECIFICATIONS
ASSUME SUITABLE VALUES FOR VARIABLES
DESIGN COMPUTATIONS
PERFORMANCE SPECIFICATIONS
COMPARE THE COMPUTED AND DESIRE DEVELOPMENT
IS PERFORMANCE O.K ?
NO
YES
ADJUST VALUES OF VARIABLES
A

Design Considerations

2. DESIGN CONSIDERATIONS

2.1 CHOICE OF SPECIFIC MAGNETIC LOADING

Choice of the average flux in the air gap in DC machines depends on the following factors.

2.1.1 FLUX DENSITY IN TEETH

If a high value of flux density is assumed for the air gap, the flux density in the armature teeth also becomes high. The value of the air gap flux density should be so chosen that the flux density at the root of the teeth does not exceed 2.2 wb/m^2, (Theoretical Max.value) otherwise the mmf required for the teeth would become excessively large which should mean that the field mmf should be made large hence copper losses. The magnatic circuit of a DC machine is shown in fig.2.1.

2.1.2 FREQUENCY

When the machine rotates, the armature magnetic circuit alternately comes under the influence of north and south poles. If the frequency of flux reversal is high, iron losses in armature core and teeth will be high. Therefore we should not use a high value of flux density in the air gap of machines which have a high frequency.

2.1.3 SIZE OF THE MACHINE

As the diameter of the machine increases, width of the tooth also increases permitting a increased value of gap flux density without causing saturation in the machine.

2.2 CHOICE OF AMPERE CONDUCTORS PER METER

The following factors affect the choice of Ampere conductors per meter.

2.2.1 TEMPERATURE RISE

A higher value of Ampere conductors per meter results in higher temperature rise of the windings. Hence it should be used only in machines which can withstand higher temperature rise. Also the ventilation factor plays a very important role in the selection of Ampre conductor per meter.

2.2.2 SPEED OF THE MACHINE

If the speed of the machine is high, the ventilation of the machine will be better and hence greater losses can be dissipated. Thus a higher value of Ampere conductors per meter can be selected for high speed machines.

2.2.3 VOLTAGE

In high voltage machines large space is required for insulation and therefore less space for conductors. This means for a high voltage machine, we must use a small value of Ampere conductor per meter.

2.2.4 SIZE OF THE MACHINE

In large machine it is easier to accommodate conductors. For given geometry of armature core, the slot area is proportional to square of Armature diameter. Therefore greater the diameter of the machine greater is the value of Ampere conductor per meter which can be employer for it.

2.2.5 ARMATURE REACTION

If a high value of ampere conductors per meter is used, the armature mmf becomes high or in other words the armature becomes magnetically stronger. This means that under load conditions there will be greater distortion of field form resulting in large reduction in the value of flux. In order to prevent this, field will have to be made stronger. Field mmf will have to be increased. This means that the cost of conductors used in the machine would go up.

2.2.6 COMMUTATION

A machine designed with high value of ampere conductors per meter will either have a large number of conductors or small armature diameter.

The machine designed with large number of coils will have a large number of turns in each coil. The inductance of the coils is proportional to the square of the number of turns. Using small armature necessitates deep slots. Deep slots increases the inductance of armature.

Therefore increasing the armature conductor per meter increases armature inductance. The reactance voltage in coils undergoing commutation is directly proportional to the inductions. Reactance voltage delays commutation. Hence larger values of ampere conductors per meter worsens the commutation conditions of the machine.

2.3 CHOICE OF THE NUMBER OF POLES

2.3.1 FREQUENCY

Frequency of flux reversal increases linearly with the number of poles. The frequency of alterations of flux in DC machine should not be very high as it would give rise to excessive iron losses is armature teeth and core. Generally the value of the frequency of flux reversals lies between 25-50 Hz. In certain cases such as DC turbo generators this is a deciding factor. Whem we increase the number of poles the dimensions of the machine decreases which is shown in fig 2.2 . But the design is complicated for a larger pole machine.

2.3.2 WEIGHT OF IRON PARTS

YOKE AREA

Flux carried by yoke is inversely proportional to the number of poles. Therefore by using greater number of poles the area of cross section of the yoke is proportionally decreased.

ARMATURE CORE AREA

The weight of iron in the core can be decreased by using a large number of poles but the increase in the number of poles would result in higher iron loss in the armature owing to increased frequency of flux reversal.

OVERALL DIAMETER

In a machine which uses lesser number of poles, field mmf per pole increases. As a result the number of turns and hence height of the pole increases. Since overall diameter of the machine depends on height of field. Hence more number of poles decreases overall diameter and hence weight of Iron is decreased.

2.3.3 WEIGHT OF COPPER

ARMATURE COPPER

The portion of conductors responsible for emf production is called active copper. Hence the portion of conductor embedded in slots is active copper. The portion of conductor in overhang is called inactive copper. Length of overhang decreases with the increases in number of poles. Hence for a machine with less number of poles, the length of inactive increases and hence the total copper weight increases.

FIELD COPPER

Field mmf per pole varies inversely with the number of poles. Cross sectional area of the pole in a machine with lesser number of poles is greater than the area of pole in a machine with larger number of poles. Hence length of mean turn is also greater in the machine with lesser number of poles. Thus the total weight of field copper decreases with increase in the number of poles.

2.3.4 LENGTH OF COMMUTATOR

The number of brush arms employed is equal to the number of of poles in case of machines with lag winding. In machines with wave winding number of brush arms is two but usually number of brush arms are equal to the number of poles. Length of brushes required in each brush arm is reduced with increase in number of poles. This results in reduction in length of commutator and length of the machine.

2.3.5 LABOUR CHARGES

Number of conductors increases with the number of poles and hence the number of armature coils also increase. As a result number of commutator segments also increase with the number of poles.

The number of field coils is equal to the number of poles. All the above factors lead to larger labour charges.

2.3.6 FLASH OVER

As the number of poles increase, number of brush arms also increase. Distance between brush arms decrease. Therefore in high voltage machines there is a possibility of flash over between brushes.

2.3.7 DISTORTION OF FIELD FORM

Armature mmf per pole varies inversely with number of poles. Hence with smaller number of poles, armature mmf per pole increases resulting in distortion of field form and reduction in flux under load conditions. Distortion is flux causes poor commutation conditions and sparking while reduction in flux causes lower emf.

2.4 CHOICE OF CORE LENGTH

2.4.1 COST

Manufacturing cost of a machine with large core length is small. This is because proportion of inactive copper to active copper is smaller, greater the length of the core. Therefore it is desirable to have a long core.

2.4.2 VENTILATION

Ventilation of machines with large core lengths is difficult since the central portion of the core trends to attain a higher temperature rise. Hence ventilating ducts must be provided for very long cores.

2.5 CHOICE OF ARMATURE DIAMETER

The following factors have to be considered while selecting armature diameter.

2.5.1 PERIPHERAL SPEED

The peripheral speed has between 15 to $50ms^{-5}$ the lower values corresponding to low speed machines. The value of peripheral should not normally exceed 30 m/s. If this speed is exceeded the binding wire for the overhang should be extra strong. This is done to prevent the overhang flying out due to excessive centrifugal force.

2.5.2 POLE PITCH

The pole pitch may be used as a check for the number of poles. The normal pole pitch values are

Poles	Pole pitch mm
2	Upto 240
4	240 - 350
6	350 - 450
above 6	450 - 500

The pole Proportions are shown in fig.2.3

2.6 LENGTH OF AIR GAP

2.6.1 ARMATURE REACTION

In order to prevent excessive distortion of field form by armature reaction, the field mmf must be made large compared to the armature mmf. A machine designed with large air gap requires large field mmf. Thus the distorting effect of armature reaction can be reduced if the length of air gap is large.

2.6.2 CIRCULATING CURRENTS

The air gap in the case of multiplier lap wound machines should be long because if it is small a slight irregularity in the air gap would result in large circulating currents.

2.6.3 POLE FACE LOSSES

If the length of air gap is made large, the variations in air gap flux density due to slotting is small. Therefore pulsation loss in the pole face decreases if the length of air gap is increased.

2.6.4 NOISE

Operation of machine with large air gap is comparatively quiet.

2.6.5 COOLING

Large air gaps providing better ventilation.

2.6.6 MECHANICAL CONSIDERATIONS

With small air gaps there is a greater possibility of appreciable unbalanced magnetic pull developing and causing rotor to foul with stator. Therefore air gap should be large enough to avoid this.

2.7 NUMBER OF ARMATURE SLOTS

The following factors should be considered while selecting the number of armature slots.

2.7.1 MECHANICAL DIFFICULTIES

If a large number of slots are used, the slot pitch becomes smaller and hence width of tooth gets smaller. This may lead to contraction difficulties.

2.7.2 COOLING OF ARMATURE CONDUCTORS

If a large number of slots are chosen, the number of conductors per slot is loss and hence only a few conductors are bunched together. Thus better cooling of armature conductors occurs.

2.7.3 FLUX PULSATION

Flux pulsations (ie) changes in air gap flux due to slotting give rise to eddy current losses in the pole faces and causes magnetic noise. With larger number of slots, the flux pulsations are reduced and therefore there is a reduction in pole face losses and noise in the machine.

2.7.4 COMMUTATIONS

Pulsations and oscillations of the flux under the interpole must be avoided as they cause sparking. A large air gap and a large number of slots helps to reduce the effect of slotting upon the flux under the interpole.

2.8 SLOT DIMENSIONS

The following points should be considered when fixing the dimensions of the slot.

2.8.1 EXCESSIVE FLUX DENSITY

The dimensions of the slot should be so chosen that it does accommodate the armature conductors and the insulations without producing excessive flux density in the teeth. Since slots are parallel sided, the teeth are tapered and hence flux density at 1/3 height from root should not exceed 2.1 wb/m^2. The typical cross section of an armature slot is shown in fig 2.4.

2.8.2 FLUX PULSATION

Wide open slots produce greater pulsations of the flux in the air gap then slots with narrow openings. Since flux pulsation causes extra iron loss and affects commutation, slots should not be to wide.

2.8.3 EDDY CURRENT LOSS IN CONDUCTORS

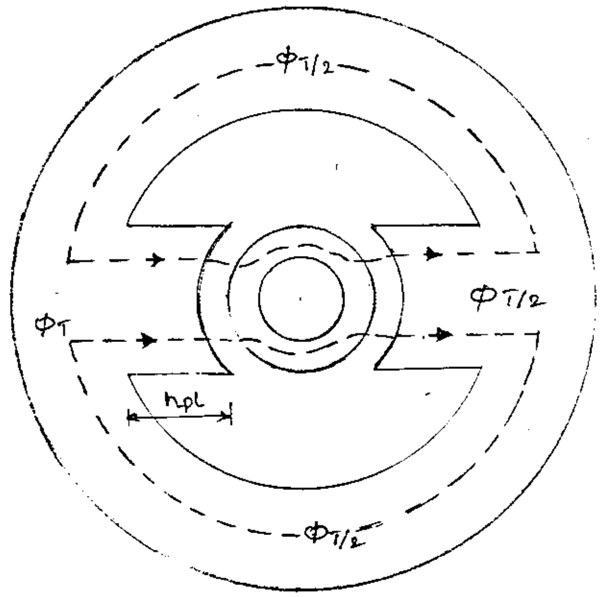
With conductors having large depths the eddy current loss in conductors increases. Therefore depth of conductors should be limited to 19mm for 25 Hz machines and 15 mm for higher frequencies. The depth of slot in normal large size machines should be limited to such a value that is just sufficient to accommodate a 2 layer winding in which the conductor depth is about 19mm.

2.8.4 REACTANCE VOLTAGE

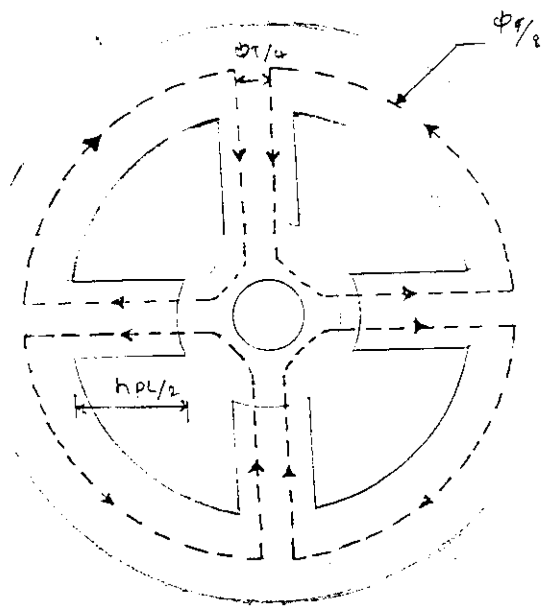
With deep slots, the specific permeance goes up and hence the reactance voltage is high. The reactance voltage retards commutation and hence this is objectionable in non interpolar machines. Therefore in non interpolar machines, ratio of slot depth to slot width is not allowed to exceed 4. For machines with interpolse deeper slots may be used.

2.8.5 MECHANICAL DIFFICULTIES

Due to deep slots, thickness of teeth at the root may become too small in which case flux density at 1/3 height from root may exceed permissible limits. Additional support have to be provided to teeth at the ventilating ducts.



A.2 POLE MACHINE



B. 4 POLE MACHINE

FIG 2.2. DECREASE IN MACHINE WITH INCREASE IN NUMBER OF POLES

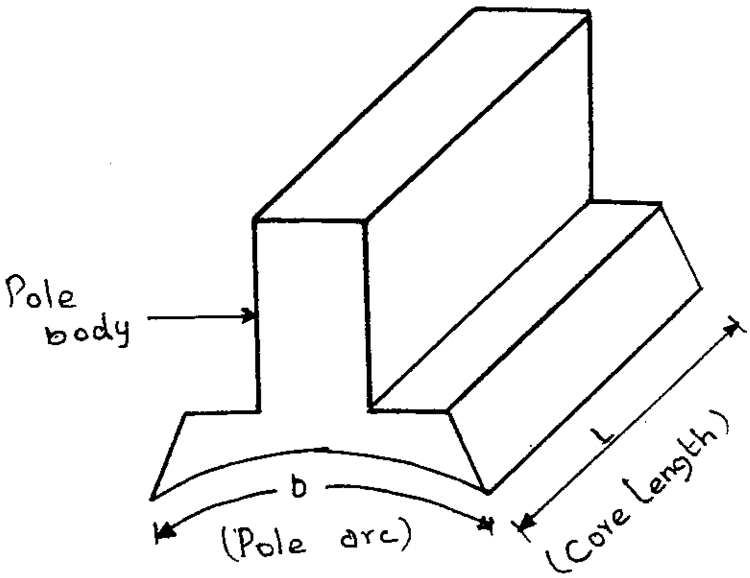


FIG. 2.3. POLE PROPORTIONS

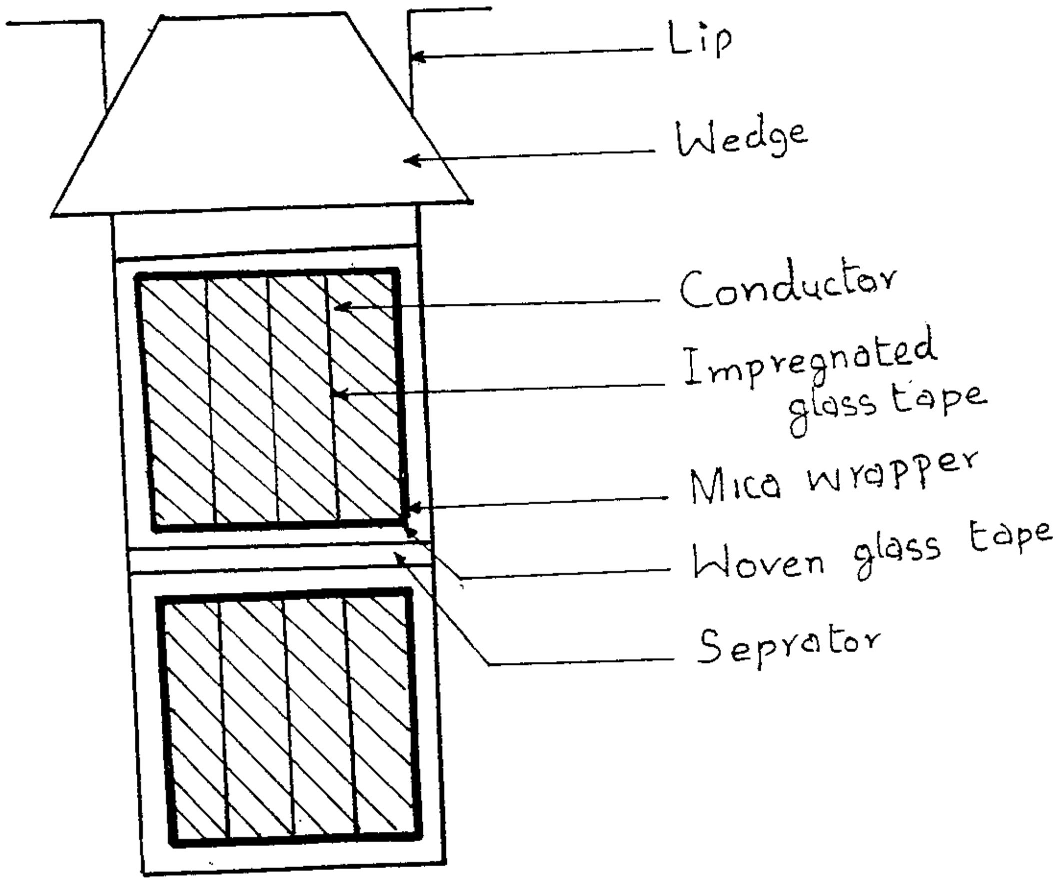


FIG. 2.4. CROSS-SECTION OF AN ARMATURE SLOT

Design Procedure

CHAPTER III

4. DESIGN PROCEDURE

MAIN DIMENSIONS

1. Output coefficient Co = π^2 Bav. q x 10^{-3} 3.1

where Bav = Average flux density in air gap in Tesla or wb/m^2 (Magnetic loading)

q = Armature Ampere conductors/metre (electrical loading)

Bav and q are selected from Design data book page 123 Table 6.2

2. $D^2 L$ = Pa/$C_o n$ metre^3

Pa - Armature power developed in the machine

n - Speed in rps.

3. $D = \sqrt[3]{\left(\frac{Pa}{Co\ N}\right)\left(\frac{P}{\pi K_1}\right)}$ metres 3.2

D - Dia of core

P - No of poles

K_1 - L/τ ratio = (0.45 to 1.1)

τ - π D/P

Check

1. Peripheral velocity

Peripheral velocity Va should not exceed 30 metres per sec. At best it should not exceed 50 ms^{-1} at any case.

2. Armature Ampere turns

Armature Ampere turns per pole ATA should be within limits.

3 $$L = K_1 \frac{\pi . D}{P} \text{ metres}$$

L = Length of core.

4. Number of ventilating ducts

$$N_{ad} = L/0.07$$

Correct it to nearest whole number of reject fraction (ie) one duct of every 7 cm.

Each duct has a width of 1 cm.

5. Nett Length of Iron

$$L_i = [L - (n_d - w_d)] K_i$$

K_i = Stamping stacking factor. Slightly lesser than 1.

6. Length of Air gap

$$l_g = \frac{(0.5 \text{ to } 0.7) AT_a}{800.000 \text{ kg Bg}} \quad .....3.3$$

Kg - 1.15 - gap expansion factor

Bg - maximum flux density in Air gap in Table

Bg - Bav/ψ

8. DESIGN OF ARMATURE

CALCULATION OF NUMBER OF SLOTS

(i) Slot pitch

$$Y_s = \pi . D/S \quad m$$

Slot pitch should vary between 0.025 to 0.035m except in the case of very small machines.

(ii) Slot per pole

$$S_P = S/P$$

Slots per pole should range between 9 and 16. Using the above two criteria (ie) slots per pole and slot pitch, the maximum & minimum number of slots are fixed.

(iii) Conditions to be satisfied for number of slots

(a) $S \neq X . P/2$

X - any integer

The number of slots should not be multiple of pair of poles.

(b) $\psi S/P = x + 0.5$

x - any integer

ψ - ratio of pole are to pole pitch.

This conditions may not be possible to be satisfied in all cases.

(c) $$\frac{EP}{15} \leq C \leq \frac{Dc}{4}$$

Dc - Diameter of the commutator in mm.

(d) Z_s - Conductor per slots

Z_s - Should be an even number or even integer.

9. Slot Depth

Sloth depth can be assumed from the table given below.

(Sawhney page 528 table 9.7)

Diameter of Armature (m)	Slot depth (mm)
0.15	22.5
0.20	27.5
0.25	32.5
0.30	37.5
0.40	42.5
0.50	45.0

10. Current per winding

I_w = Kw/ V.A

A - Number of parallel paths

A = P for lap A = 2 for wave.

11. Cross sectional area = Kw/V.A $\cdot \delta_a$

δ_a - Current density - 4 to 5 A/mm

12. Assuming simplex winding

$$\text{Height of winding} = \frac{2 \quad Kw}{V.A.\,\delta_a \; D_s} \text{ mm}$$

D_s - Depth of slot

13. Total height of slot $= \dfrac{2.\ KW}{VA\ \delta a\ D_s} + 8.5 \times 10^{-3}$ mm

14. Depth of Core Dc $= \dfrac{\phi}{2\ Bc\ L_i}$ metre

Bc - flux density in core - 1.25 tesla

l_i - Length of iron

ϕ - Main flux

15. Diameter of shaft (max permissible)

$$D_{sh} = D - [\ 2h_s + 2Dc]\ \text{metres}$$

DESIGN OF FIELD SYSTEM

SHUNT FIELD

1. **Leakage Coefficient C_1**

The values of leakage coefficient can be assumed from the given table.

KW	Leakage coefficient
50	1.12 - 1.25
100	1.11 - 1.22
150	1.1 - 1.2
500	1.09 - 1.18
1000	1.08 - 1.16

2. **Flux in the poles**

$$\phi_p = C_1 \cdot \phi \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

3. **Area of Pole Core = A_p**

$$A_p = \phi_p / B_p \quad m2$$

B_p = flux density in pole shoe

4. **Length of pole - L_p**

$$L_p = L - 1.5 \text{ cm}$$
$$= L - o.15$$

5. **Width of pole - W_p**

$$W_p = \frac{C_1 \Phi}{B_p K_s L_p} \quad \ldots\ldots 3.5$$

6. **Ampere turns reqd. at full load AT_{fl}**

$$AT_{fl} = (1.1 \text{ to } 1.25)\ AT_a \quad \ldots\ldots. 3.6$$

AT_a = Armature Ampere Turns per pole

7. **Ampere Turns per unit height**

$$AT_{uh} = 10^4 \times \sqrt{q_f \; S_s \; d_f}$$

d_f = depth of field winding

S_f = Copper space factor

q_f = permissible loss per unit winding surface

8. **Height of field winding - h_f**

$$h_f = \frac{AT_{fL}}{AT_{uh}} \quad \text{metres}$$

9. **Depth of field winding**

Page 541 Sawhney Table 9.8

Armature Diameter (m)	Winding depth (mm)
0.20	30
0.35	35
0.50	40
0.65	45
1.00	50
1.0 & above	55

10. **Voltage per field winding - E_f**

$$E_f = \frac{0.8V}{p} \text{ Volts}$$

11. **Length of mean turn of shunt field. L_{mts}**

$$Lmts = 2(wp + LP) \quad m$$

12. **Cross sectional area of field conductor -C_{fs}**

$$C_{fs} = \frac{AT_{fL} \cdot L_{mts}}{E_f} \quad m^2$$

13. **Diameter of bare conductor - D_{bs}**

$$D_{bs} = \sqrt{\frac{4}{\pi} \quad C_{fs}}$$

C_{fs} = Cross sectional area of conductor

SERIES FIELD DESIGN

I Pure Series Machine

1. Ampere turns required AT_{ss}

$$AT_{ss} = (1.1 \text{ to } 1.2)\ AT_a$$

where AT_a = Ampere turns per pole (Armature).

2. Turns in the series coil. T_{ss}

$$T_s = \frac{At_{ss}}{Ia.P} \quad \text{turns}$$

Ia = armature current

P = Poles

3. Cross sectional area of series field C_{ss}

$$C_{ss} = Ia/\delta \quad mm^2$$

= Current density - 4 to 5 A/mm^2

4. Diameter of bare conductor - D_{bss}

$$D_{bss} = \sqrt{\frac{4}{\pi} C_{ss}} \times 10^{-3} \quad \text{metres}$$

DESIGN OF INTERPOLES

1. Length of Interpole L_{ip}

L_{ip} = (0.6 to 0.8) L metres......3.7

L = Length of armature core.

2. Width of Interpole W_{ip}

$$\frac{(1-\psi)\tau}{2} \geqslant W_{ip} \geqslant 1.5\, y^{s}$$

3. Length of air gap under the Interpole - L_{gi}

L_{gi} = (2 to 3) lg. metres

lg = length of air gap under pole.

4. Maximum flux density in the air gap under the Interpole -B_{gi}

$$B_{gi} = 2.\, Zs \frac{I_a}{A} \quad \frac{\lambda L}{L_{ip}} \quad \frac{1}{V_a\, t_c}$$

V_a = Dn

λ – Values page 563 Sawhney Eqn 9.72

5. ampere Turns required

(i) If compensating winding is present in the pole shoe (To compensate armature reaction).

$$AT_i = 800{,}000 \; Kgi \; Bgi \; Lgi + (AT_a - AT_c)$$

$$AT_c = \psi \; AT_a \qquad \ldots\ldots.3.8$$

$$AT_a = \frac{I_a}{A} \; \frac{Z}{2P}$$

(ii) Without compensating winding

$$AT_i = 800{,}000 \; Kgi \; Bgi \; lgi + AT_a \quad \ldots\ldots3.9$$

DESIGN OF COMMUTATOR AND BRUSHES

1. Number of Brushes - N_b

$$N_b = \frac{2 I_a}{70 P} \quad ....3.10$$

P - Poles

I_a - armature current

2. Width of brush - W_b

$$W_b = \frac{2.5 \pi DC}{C} \quad \text{Metres} \quad ...3.11$$

3 Current carried by each spindle = $\frac{2 I_a}{p}$ ampere

4. Length of brush = $\frac{A_b}{N_b \cdot W_b}$ metres ...3.12

5. Length of commutator

$$L_c = N_b (l_b + 0.5 \text{ cm}) + C_1 + C_2$$

C_1 - Clearance for brush holder 1 to 3 cm

C_2 - Clearance for edges not allowing current to end plate 1 to 2.5 cm

6. Width of commutator segment - W_c

$$Wc = \frac{\pi D_c}{C} - (0.2 \text{ or } 0.1) \text{ cm}$$

DESIGN OF ARMATURE WINDING

1. Simplex Lap Winding

(i) Back pitch - Y_b

$$Y_b = \frac{2C}{P} \pm K$$

K may be integer or fraction which makes the whole relation as an odd integer near 2C/P.

(ii) Winding pitch Y

Y = +2 Progressive winding

Y = -2 Retrogressive winding

(iii) Front pitch Y_f

$$Y_f = Y_b - Y$$

(iv) Commutator pitch $Y_c = Y/2$

2. Simplex Wave Winding

(i) Back pitch - Y_b

$$Y_b = \frac{2C}{P} \pm K$$

K may be integer or fraction which makes the whole relation as an odd integer near 2C/P.

(ii) Winding pitch Y

$Y = +2$ Progressive winding

$Y = -2$ Retrogressive winding

(iii) Front pitch Y_f

$Y_f = Y_b - Y$

(iv) Commutator pitch $Y_c = Y/2$

3. Duplex Lap winding

Back pitch $Y_b = \frac{2C}{P} \pm K$ Odd integer

Commutator pitch $Y_c = \pm 2$

Winding pitch $Y = \pm 4$

Front pitch $Y_f = Yb - Y$

4. Duplex Wave Winding

Back pitch $Y_b = \frac{2C}{P} \pm K$ (Odd integer)

Winding pitch $Y = \frac{2C \pm 4}{P/2}$

Comutator pitch $Y_c = \frac{C \pm 2}{P/2}$

Front pitch $= Y - Y_b$

LOSSES AND EFFICIENCY CALCULATION

1. Brush Contact Loss $= V_b \; I_a$ 3.13

   V_b = Brush Voltage Drop

   I_a = Armature current

2. Brush Friction Loss $= \mu P_b \; A_b \; P \; V_c$ 9.81 Watts

   μ = Coefficient of Friction

   P_b = Brush Pressure (kg/m^2)

   V_c = Peripheral Velocity of Commutator

3. Function and Windage Losses

Peripheral Speed m/s	Losses Percentage of Output
10	0.2
20	0.4
30	0.6
40	0.9
50	1.2

4. Loss in armature teeth

   4.a Weight of armature teeth $= S \; W_t \; L \; D_S$ 7800 kg

   S = Number of slots

   W_t = Width of teeth

   L = Length of core

   D_s = Depth of slot

4.b Slot Pitch at 1/3 ht from root $= \pi \left(D - \frac{4 d_s}{S}\right) / S$

4.c Width of teeth at 1/3 ht from root

W_{t13} = Slot pitch at 1/3 ht from root - W_s

W_s = Width of slot

4.d Flux density at 1/3 ht from root =

$P. \phi / 0.67 \, S \, L_i \; W_{t13}$

4.e Specific iron loss in teeth

slit = $0.06 \, f \, B_m^2 + 0.008 \; f^2 \; B_m^2 \; t^2$

f = frequency of flux reversal

B_m = Flux density at 1/3 ht from root

t = thickness of lamination

5. Iron loss in teeth = Sp.iron loss * Wt of armature teeth

5.a Weight of armature core = volume * 7800 Kg

5.b Specification iron loss in core = SILC

silc - $0.06 \, f B_m^2 + 0.005 \; f^2 B_m^2 \; t^2$

f = frequency of flux reversal

B_m = max. flux desity

t = thickness of lamination

5.c Iron loss in core = silc * weight of armature core watts.

6. Copper losses

6.a Armature losses

6.a.1 resistance of armature

$$= \frac{zL \quad 0.021}{2\ [C\ S\ area]\ 4} \text{ Ohms}$$

6.a.2 Armature copper loss $= I_a^2 \; R_a$ watts

6.b Shunt field loss

6.b.1 resistanceof field =

T_f 0.0021 L_{mt} / (CS area) ohms

6.b.2 Field loss = P R_f I_f^2 watts

6.c Series field loss

6.c.1 Resistance of series field =

T_s 0.021 L_{mt} / (CS area) Ohms

6.c.2 loss in series field =

P R_s I_a^2 watts

7. Effeciency =

$$\frac{\text{Input power - Losses}}{\text{Input Power}} \times 100\%$$

Algorithm and Flow Chart

CHAPTER IV

ALGORITHM AND FLOW CHART

Algorithm for software development is described below;

4.1 Algorithm

The various steps involved in the design are listed below;

1. The output rating, line voltage, speed are given as input.
2. Electric magnetic loadings are stored in the computer in a tabulator form.
3. Specify whether the machines to be designed is a generator on a motor.
4. Assume L/C = 0.90 compute output coefficient, Diameter of armature and peripheral velocity.
5. Check for the peripheral velocity. if peripheral velocity is less than or equal to 30 m/s go to step.
6. otherwise reduce L/C ratio and goto step.
7. Compute the main dimensions and give the max & min number of slots.
8. Input the no of slots.
9. Compute the slot dimensions and determine the type of winding and winding details.
10. Design field circuit.
11. Select a suitable for leakage coefficient.
12. Compute the diameter of shaft.
13. Design the interpole compute the dimensions of interpole and air gap under the interpole.

14. Design commutator & brushes compute the no of brushes commutator segments, length and area of brush.
15. Compute the brush contact loss friction and windage loss, Armàture copper loss, Iron loss in core & teeth.
16. Compute total losses and efficiency.
17. print design data.

The details flow-chart is given in Fig 4.1

Program and Simulations

INTRODUCTION TO Turbo C

In recent years, there has been a major trend toward the use of C among serious programmers. Among the many reasons for C's popularity are the following:

* C is a flexible, high-level, structured programming language.

* C includes certain low-level features that are normally available only in assembly or machine language.

* Programs written in C compile into small objects programs that execute efficiently.

* C is widely available. Commericial C compilers are available for most personal computers, minicomputers, and mainframes.

* C is largely machine-independent. Programs written in C are easily ported from one computer to another.

```
/**********************************************************************

        COMPUTER  AIDED DESIGN OF DC MACHINES

                        by
                            ** BHARATHAN.A
                              ** PAUL RAJ.A
                                ** VELMURUGAN.S

                   UNDER THE GUIDANCE OF

                                  ** Dr.K.A.PALANISWAMY

**********************************************************************/

      /* COMPUTER AIDED DESIGN OF DC MACHINES */
      /* DESIGN OF MAIN DIMENSIONS*/
      # include <stdio.h>
      # include <math.h>
      # include <float.h>
      # define PI 3.141593
          main()
               {
        double Bave,Ati,Lam,LBT,CO,Bmax,ac,Ds,Df,IW,Ww,W,M,E,V1,Ia;
        double o,d,o1,a1,Dshaft,Dsfc1,D,d1,L,Tou,n,nr,Atp,Lg,PA,Li;
        double Haw,Hs,V,C,Atpuh,Atf,Wp,Dsfc,Ldi,Lb,Wc,Vc,X3,Tts,Z1;
        double Iarm,Iw,w,Cl,Ws,If,Il,Ca,v,Dsh,X,Ap,Lp,Ts,Tss,g7,Nbi,Ti,P
fs;
        double lobw,lob,lof,lobf,lofw,f,l1,ws,wat,wt,y13,w13,b13;
        double Dbss,Pout,Css,Itss,Atss,Lip,Wip,ldi, Dc,Kc,Wb,Ab;
        double S,sp,P,Z,c,Pc,Pw,Pf,Y1,choice,Ats,Its,Tc,a;
        double Lc,Fluxpp,Fluxp,Hf,Ef,Lmts,Csf,Isf,Cas,Bm1,lost,wac,losc,
,ra,loa,rf,losst,eff;
       int Smn,Sm,Nb,rr,Y;
                  clrscr();
                printf("\n computer aided design of dc machine\n ");
                printf("\n enter the specifications:\n");
                printf("\n required o/p in KW=");
                scanf ("\n %lf",& Pout);
                printf("\n voltage rating in volts=");
                scanf("\n%lf",&V1);

                /* MAIN DIMENSIONS */

                printf("\n design of main dimensions ");
      printf(
```

```
"\n**For Economy And Efficient Design For Your o/p Rating");
  printf("\nYou Can go Upto The Speed:\n");

if (Pout<=2.Ø){
   printf("\n We Can Go 125Ø - 3ØØØ rpm:\n");
   P=2;
   }
else if (Pout<=75.Ø){
   printf("\n We Can Go 9ØØ - 175Ø rpm:\n");
         P=4;
         }
else if (Pout <=2ØØ.Ø){
   printf("\n We Can Go Upto 12ØØ rpm:\n");
     P=6;
     }
else if (Pout<=5ØØ.Ø){
   printf("\n We Can Go Upto 1ØØØ rpm:\n");
     P=8;
     }
else if (Pout<=15ØØ.Ø){
     printf("\n We Can Go Upto 9ØØ rpm:\n");
       P=1Ø;
       }
else if (Pout<=25ØØ.Ø){
     printf("\n We Can Go Upto 4ØØ rpm:\n");
       P=12;
       }
else {
     printf("\n We Can Go  Upto 3ØØ rpm:\n");
       P=14;
       }

     printf("\n Enter The Choice Of Speed In rpm:");
     scanf("%lf",&nr);
        n=nr/6Ø;
printf("\n Give The Electric & Magnetic Loading Vaules\n");
printf("\nTable of electric & magnetic loadings\n");
printf("\n________________________________________________
____________\n");
printf("  Output(KW)| Bmax(Tesla)|  ac(A/M)  |OUTPUT(KW) | Bmax(Te
ac(A/M) |");
printf("\n________________________________________________
____________");
printf("\n  5        | Ø.575      | 16ØØØ     |   5ØØ     |  Ø.915
 36ØØØ  |");
printf("\n  1Ø       | Ø.65Ø      | 18ØØØ     |   75Ø     |  Ø.948
38ØØØ  |");
printf("\n  2Ø       | Ø.7ØØ      | 2ØØØØ     |  1ØØØ     |  Ø.962
4ØØØØ  |");
printf("\n  3Ø       | Ø.73Ø      | 22ØØØ     |  15ØØ     |  Ø.97Ø
42ØØØ  |");
```

```
    printf("\n  40       | 0.750      | 24000      |  2000      |  0.978
44000  |");
    printf("\n  200      | 0.876      | 32000      |  50        |  0.775
25000  |");
    printf("\n  300      | 0.890      | 34000      |  100       |  0.825
26000  |");
    printf("\n  400      | 0.908      | 35000      |            |
       |");
    printf("\n___________________________________________________________
___________");

            printf("\n Enter Bmax In Tesla:");
            scanf("%lf",& Bmax);
            printf("\n Enter ac In a/m:");
            scanf("%lf",&ac);
               CO=(PI*PI* Bmax*ac/1000);
            LBT=0.80;
            printf("\n ENTER 1 FOR GENERATOR & 2 FOR MOTOR :");
            scanf("%d",&rr);

            if(rr==1)
              PA=Pout/0.92;
            else if (rr==2)
              PA=Pout*2.7/2.55;
              else
              goto xx;

        rath:    d=(PA*P)/(CO*n*PI*LBT);
                 d1=0.3333333333333333;
                 D=pow(d,d1);
                 v=PI*D*n;
                 if(v<=30.0)
                 v=v;
        else  {
          LBT=LBT-0.05;
           goto   rath;
           }

            L=LBT*PI*D/P;
            Nvd=L*100.0/7.0;
            Li=(L-(Nvd*0.01))*0.90;
            Tou=PI*D/P;
            Atp=ac*Tou/2.0;
            Bave=Bmax*0.70;
            Lg=(0.60*Atp)/(800000*1.15*Bmax);


    /* DESIGN OF ARMATURE */

            Smn=PI*D/0.035;
            Sm=PI*D/0.0250;
            printf("\nMinmum No. Of Slots :%d\n",Smn);
            printf("\n Maxmum No. Of Slots :%d\n",Sm);
            printf("\n Give The Number Of Slots You Want:\n");
        printf("\n** Note The Number Of Slots Should Multiples Of P/2:");
            scanf("%lf",&S);
```

```
sp=S/P;
  if(sp<=9)
     sp=sp+1;
  else if (sp>=16)
       sp=sp-1;
    else
       sp=sp;
S=sp*P;

if (D<=0.15){
   Ds=0.0225;Df=0.03;
   }
else if(D<=0.20){
   Ds=0.0275;Df=0.03;
   }
else if(D<=0.25){
   Ds=0.0325;Df=0.035;
   }
else if(D<=0.30){
   Ds=0.0375;Df=0.035;
   }
else if(D<=0.40){
   Ds=0.0425;Df=0.04;
   }
else if(D<=1.00){
   Ds=0.045;Df=0.04;
   }
else {
   Ds=0.045;Df=0.055;
   }

   Il=(Pout*1000.0)/Vl;
   M=PA*nr;
   if(M<=10000.0){
     Iarm=6.7;
     If=0.025*Il;
     }
   else if (M<=20000.0){
     Iarm=6.0;
     If=0.022*Il;
     }
   else if (M<=40000.0){
     Iarm=5.3;
   If=0.017*Il;
     }
   else if (M<=100000.0){
     Iarm=4.6;
   If=0.0135*Il;
     }
   else if (M<=200000.0){
     Iarm=4.0;
   If=0.008*Il;
     }
   else {
```

```
Iarm=3.2;
If=0.004*Il;
}
Ia=Il-If;
if(rr==1)
    E=Vl+Iarm;
else
E=Vl-Iarm;
Y1=PI*D/S;
   getchar();

/* design of field system */

Fluxpp=(Bave*PI*D*L)/P;
if (Pout<=50)
 Cl=1.175;
else if (Pout<=100)
   Cl=1.165;
else if(Pout<=150)
 Cl=1.150;
else if (Pout<=500)
 Cl=1.135;
else
  Cl=1.12;
Fluxp=Cl*Fluxpp;
Ap=Fluxp/1.5;
 Lp=L-0.015;
printf("\nGIVE 's' FOR SHUNT 'S' FOR SERIES & 'C'  FOR CUMMULATIVE:")
   choice=getchar();
     if(choice=='s'){
     printf("\n SHUNT FIELD DESIGN ");
     Atf=Atp*1.15;
     Atpuh=10000*(0.62*700*Df);
     printf("\n DEPTH OF FIELD WINDING  :%10.3lf",Df);
     printf("\n AT PER UNIT HIEGTH OF FIELD  :%10.3lf\n",Atp
     Hf=Atf/Atpuh;
     Ef=0.80*Vl/P;
     Wp=0.08;
     Lmts=2*(Wp+Lp);
     Csf=(Atf*0.02*Lmts)/Ef;
     Dsfc1=(4*Csf/PI)/1000;
     Tfs=(0.62*Df*Hf)/(Csf/1000000);
     printf("\n C.S OF AREA OF SHUNTFIELD WIRE=%10.3lf\n",Cs
     printf("\n SHUNT FIELD turns =%10.3lf\n",ceil(Tfs));
     Isf=Atf/Tfs;
     printf("\n SHUNT FIELD CURRENT =%10.3lf\n",Isf);
     }

        if (choice =='c'){
        printf("\n SERIES FIELD DESIGN - COMPOUND M/C");
        Ats=0.25*Atp;
```

```
            Its=Pout/(Ia*P);
            Ts=2*(ceil(Its/2));
            Cas=Ia/4.5;
            Dsfc=((16*Cas*Cas)/(PI*PI))/1000;
    printf("\n AT IN SERIES FIELD WINDING  :%d\n",Ats);
    printf("\n CURENT IN SERIES FIELD :%f\n",Its);
    printf("\n C.S AREA OF SERIES FIELD CONDUTORS :%lf\n",Cas);
    printf("\n DIAMETER SERIES FIELD CONDUCTOR :%lf\n ",Dsfc);
        }
        if (choice=='S'){
        Atss=1.2*Atp;
        Itss=Atss/(Ia*P);
        Tss=2*ceil(Itss/2);
        Css=Ia/4.5;
Dbss=(16*Css*Css/PI*PI)/1000;
printf("\n AT OF SERIES FIELD   :%10.3lf\n",Atss);
printf("\n CURRENT IN SERIES FIELD :%10.3lf\n",Itss);
printf("\n TURNS IN SERIES FIELD :%10.3f\n",Tss);
printf("\n C.S AREA OF FIELD CONDUCTORS :%10.3lf\n",Css);
printf("\n DIAMETER OF SERIES FIELD CONDUCTORS :%10.3lf\n",Dbss);
        }

 if ((choice != 's') && (choice !='S') && (choice !='C'))  {
xx: printf("\n WRONG INPUT ?-----:TRY AGAIN ! ");
     goto end;
        }

     /* INTER POLE DESIGN */

    Lip=0.75*L;
    Ldi=2.5*Lg;
    Wip=(S/P)*1.5;

    /* DESIGN OF COMMUTATOR */

    printf("\n COMMUTATOR DESIGN\n");
      if(Vl<=160)Kc=0.80 ;
      else if (Vl<=200) Kc=0.75;
      else if (Vl<=300) Kc=0.68;
      else Kc=0.62;
      Dc=D*Kc;
                o1=Pout*1000.0/n;
                Dshaft=0.0055*pow(o1,d1);
      Nbi=(2*Ia)/(70*P);
      Nb=ceil(Nbi)+1;
      Wb=(2.5*PI*Dc*100)/S;
      Ab=(2*Ia)/(6*P);
      Lb=Ab/(Nb*Wb);
      Lc=Nb*(Lb+0.50)+2+2;
```

```
Wc=(PI*Dc*100/S)-(0.15);
    if(Vl<=100)Lam=0.000008;
    else if(Vl<=500) Lam=0.000006;
    else Lam=0.000004;
    Vc=PI*Dc*n;
    Tc=(PI*Dc/S)/Vc;   getch();

  /* ARMATURE WINDING DESIGN */

      Z=E*a/(Fluxpp*n*P);
     Z1=ceil(Z/(2*S))*2;
      Z=Z1*S;
      Iw=(Pout*1000)/(Vl*a);
          Haw=(2*Pout*1000)/(Vl*a*5*Ds);
   W=3*(2*Haw/(Ds*700));
   Ww=W+2.5;
   C=S*3;
   Hs=(Haw/1000)+(8.5/1000);
/* Dsh=D-(2*Hs)-(2*Dc);     */
   o1=Pout*1000/n;
   a1=pow(o1,d1);
   Dshaft=0.0055*a1;
   Ca=Iw/5;
   Hs=(Haw+8.5)/1000.0;
  getchar();
    Bm1=(2*(Z/S)*Ia*Lam*L)/(a*Lip*Tc*Vl);

    printf("\n DO YOU WANT COMPENSATING WINDING ?  (1/2):");
    scanf("%d",&Y);
     if(Y==1){
     Ati=(800000*1.15*Bm1*2.5*L)+(Atp-(0.65*Atp));
     Ti=ceil(Ati/Ia);
     }
     else if (Y==2){
     Ati=((800000*1.15*Bm1*2.5*L)+Atp);
     Ti=ceil(Ati/Ia);
     }
     else  {
     goto end;
     }
     printf("\n INTERPOLE TURNS :%lf\n",Ti);

      Fluxpp=(Bave*PI*D*L)/P;  getchar();
         if(Ia<=400){
 printf("\nTYPE OF WINDING TO BE USED IS WAVE WINDING \n");
    a=2;  goto wave;
    }
      else {
printf("\nTYPE OF WINDING TO BE USED IS LAB WINDING \n");
```

```
        a=P; goto Lap;
        }
        Lap: Pb=ceil(2*S/P)+1;
    printf("\n ASSUME PROGRESSIVE WINDING \n");
    printf("\n WINDING PITCH :1\n");
    Pf=Pb-2;
    printf("\n FRONT PITCH :%lf\n",Pf);
    printf("\n COMMUTATOR PITCH : 1\n");
    goto next;
    wave:  Pb=ceil(2*S/P)+1;
    printf("\n ASSUME PROGRESSIVE WINDING \n");
    Pw=(2*S+2)/(P/2);
    Pf=Pw-Pb;
    Pc=Pw/2;
    printf("\n FRONT PITCH :%lf\n",Pf);
    printf("\n COMMUTATOR pitch:%d\n",Pc);
    printf("\n WINDING PITCH :%lf\n",Pw);
    next:

    getch();
    /* computation of losses & effienciency */

        printf("\n COMPUTATION OF LOSSES AND EFFICIENY\n");


ws=Ww/1000.0;
lob=Ia*2;
lobf=Ab*Vc*P*0.15*12.5;
lobw=5*PA;
l1=lob+lobw+lobf;
wt=(PI*(D-Ds)/S)-ws;
wat=S*wt*L*Ds*7800;
y13=PI*(D-(1.33333*Ds))/S;
w13=y13-ws;
b13=P*Fluxpp/(0.67*S*Li*w13);

f=P*nr/120;
lost=((0.06*f*b13*b13)+(0.008*f*f*b13*b13*0.25))*wat;
printf("\n Iron loss in teeth :%10.3lf\n",lost);
wac=(PI*((D-2*Ds))*(D-2*Ds))/4*7800*L;
losc=((0.06*f*Bmax*Bmax)+(0.005*f*f*Bmax*Bmax*0.25))*wac;
printf("\n   Iron loss in core :%lf\n",losc);
/* lot=losc+lost;   */
ra=Z*((2*L)+(2.3*Tou)+(S*Ds))*0.021/(W*2/a);
loa=Ia*ra;
/*          if(choice=='S'){
   rf=(Tfs*0.021*2*(Wp+Lp))/Csf;
```

```
lof=P*rf*Isf*Isf;

          getch();
          }
 else{
 rf=(Tss*0.021*2*(Wp+Lp))/Css;
 lof=P*rf*Itss*Itss;
  }
printf("\n Field current loss :%lf\n",lof);    */
lof=10*loa;
losst=loa+(lof*3)+(losc*2.5)+l1;
    if(rr==1)
        losst=losst;
      else
         losst=1.2*losst;
printf("\nTotal losses :%10.3lf\n",losst);
eff=(Pout/(Pout+(losst/1000.0)))*100;
printf("\n Efficiency at F.L.:%lf\n",eff);
   end: printf("\n END: ");
   clrscr();
printf("\n                DESIGN  SHEET  SPECIFICATIONS \n");

   printf("\n OUTPUT RATING (KW) :%lf\n",Pout);
   printf("\n SPEED  IN  RPS :%lf\n",V1);
    if(rr==2)
   printf("\n CHOICE : Motor \n");
   else
    printf("\n CHOICE : Generator\n ");
    if(choice == 'S')
      printf("\n TYPE : series");
      else if (choice == 's')
      printf("\n TYPE : shunt\n");
      else
  printf("\n TYPE : cumulative\n");
printf("\n The no. of poles :%lf\n",P);getch();
       printf("\nPower developed in armature:%lf\n",PA);
       printf("\nOutput coefficient=%lf\n",CO);
       printf("\n speed in rps=%12.5lf\n",n);
      printf("\n Diameter Of Armature Core in m :%lf\n",D);
      printf("\n L / tou ratio:%lf\n",LBT);
      printf("\nLength Of Armature Core in m :%lf\n",L);
      Nvd=L*100.0/7.0;
      printf("\nNumber Of Ducts :%f\n",ceil(Nvd));
      printf("\nThe Distance Between Two Ducts :7cm");
      printf("\nDuct Width : 1 cm");      getch();
    printf("\nNett Length Of Iron  in m:%lf\n",Li);
```

```
printf("\nLength Of Air Gap in m :%lf\n",Lg);
printf("\nPeripheral Velocity in m/s :%lf\n",v);
printf("\nNo. of slots :%lf",S);
printf("\n Slot pitch :%lf",sp);
printf("\n Depth Of Slot In m:%lf",Ds);
Il=(Pout*1000.0)/Vl;
printf("\n Line ct. in A:%12.4lf",Il);
printf("\n Current in armature ( A ):%12.4lf",Ia);
printf("\n Field ct. in A :%lf",If);
printf("\n                        DESIGN OF INTERPOLE\n");
printf("\n Length of interpole in  m:%10.3lf\n",Lip);
printf("\n Width of interpole in mm :%10.3lf\n",Wip);
printf("\n Length of air gap under interpole in m :%10.3lf\n",Ldi);
printf("\n Inter pole ampere turns :%lf\n",Ati);
printf("\n Interpole turns :%lf\n",Ti);
printf("\n                   COMMUTATOR DESIGN\n");
getch(); clrscr();
printf("\n Diameter of commutator in m :%lf\n",Dc);
printf("\n No. of brushes :%d\n",Nb);
printf("\n Width of brush:%lf\n",Wb);
printf("\n USE CARBON BRUSHES ");
printf("\n Area of brush :%lf\n",Ab);
printf("\n Length of brush :%f\n",Lb);
printf("\n Length of commutator in cm :%lf\n",Lc);
printf("\n Width of commutator segment :%lf\n",Wc);
printf("\n Peripheral velocity :%lf\n",Vc);
if(choice=='s'){
   printf("\n            SHUNT FIELD DESIGN ");
   printf("\n DEPTH OF FIELD WINDING  :%10.3lf",Df);
   printf("\n AT PER UNIT HIEGTH OF FIELD  :%10.3lf\n",Atpuh);
   printf("\n C.S OF AREA OF SHUNTFIELD WIRE=%10.3lf\n",Csf);
   printf("\n SHUNT FIELD turns =%10.3lf\n",ceil(Tfs));
   }
   getch();
      if (choice =='c'){
      printf("\n      SERIES FIELD DESIGN - COMPOUND M/C");
      printf("\n AT IN SERIES FIELD WINDING  :%d\n",Ats);
      printf("\n CURENT IN SERIES FIELD :%f\n",Its);
      printf("\n C.S AREA OF SERIES FIELD CONDUTORS :%lf\n",Cas)
      printf("\n DIAMETER SERIES FIELD CONDUCTOR :%lf\n ",Dsfc);
   }
   if (choice=='S'){
   printf("\n AT OF SERIES FIELD  :%10.3lf\n",Atss);
   printf("\n CURRENT IN SERIES FIELD :%10.3lf\n",Itss);
   printf("\n TURNS IN SERIES FIELD :%10.3f\n",Tss);
   printf("\n C.S AREA OF FIELD CONDUCTORS :%10.3lf\n",Css);
   printf("\n DIAMETER OF SERIES FIELD CONDUCTORS :%10.3lf\n",Dbs
);

   }

printf("\n                 ARMATURE WINDING DESIGN");
      if(Ia<=400){
 printf("\nTYPE OF WINDING TO BE USED IS WAVE WINDING \n");
  printf("\n No. of parallel paths = 2");
  }
    else {
```

```
printf("\nTYPE OF WINDING TO BE USED IS LAB WINDING \n");
printf("\n No. of parallel paths = %lf\n",P);
        }
printf("\n No. of armature conductors :%lf\n",ceil(Z));
getch(); clrscr();
        printf("\n Conductors per slot :%lf\n",Z/S);
      printf("\n Current Per Winding:%lf\n",Iw);
printf("\n C.S.Area of armature winding in mm2 =%10.3lf\n",Iw/5.0);
printf("\n Current density  in  A / mm^2 :5\n");
printf("\n Width of winding =%10.3lf\n",Ww);
printf("\n Width of slot in mm:=%10.3f\n",Ww/1000.0);
      printf("\nDiameter of shaft in m:%lf\n",Dshaft);
      printf("\n Depth of slot in m:=%10.3lf\n",Ds);
     printf("\n Total height of slot in cm :%lf\n",Hs);
     getchar();
       printf("\n Period of commutation  in sec.:%lf\n",Tc);
       getch();    clrscr();
printf("\n Inter pole ampere turns :%lf\n",Ati);
printf("\n Interpole turns :%lf\n",Ti);
    printf("\n ASSUME PROGRESSIVE WINDING \n");
    printf("\n Winding pitch :1\n");
    printf("\n Front pitch :%lf\n",Pf);
     printf("\n Commutator pitch : 1\n");
getch();
   printf("\n          COMPUTATION OF LOSSES AND EFFICIENY\n");

   printf("\n brush contact loss :%10.3f\n",2*Ia);
  printf("\n friction  windage & brush contact loss =%lf\n",l1);

  printf("\n   Iron loss in core :%lf\n",losc);
  printf("\n Armature copper loss :%lf\n",lob);
   printf("\nTotal losses :%10.3lf\n",losst);
   eff=(Pout/(Pout+(losst/1000.0)))*100;
   printf("\n Efficiency at F.L.:%lf\n",eff);
      printf("\n END: ");
```

OUTPUT RATING (KW) : 3.0000

SPEED IN RPM :1500.000000

VOLTAGE RATING :230.000000

CHOICE : Motor

TYPE : shunt

The no. of poles :4.000000

Power developed in armature:3.176471

Output coefficient=81.424254

speed in rps= 25.00000

Diameter Of Armature Core in m :0.135422

L / tou ratio:0.800000

Length Of Armature Core in m :0.085088

Number Of Ducts :2.000000

The Distance Between Two Ducts :7cm
Duct Width : 1 cm
Nett Length Of Iron in m:0.065640

Length Of Air Gap in m :0.000946

Peripheral Velocity in m/s :10.636048

Frequency of flux reversals :50.000000

No. of slots :16.000000
Slot pitch :4.000000
Depth Of Slot In m:0.022500
Line ct. in A: 13.0435
Current in armature (A): 12.7174
Field ct. in A :0.326087

Conductors per slot :82.000000

Current density in A / mm^2 :5

Width of winding = 46.668

Width of slot in mm:= 0.047

Diameter of shaft in m:0.027128

Depth of slot in m:= 0.022

Total height of slot in cm :0.124442

Period of commutation in sec.:0.002500

Inter pole ampere turns :3118.632738

Interpole turns :246.000000

ASSUME PROGRESSIVE WINDING

Winding pitch :1

Front pitch :8.000000

Commutator pitch : 1

COMPUTATION OF LOSSES AND EFFICIENY

brush contact loss : 25.435

friction windage & brush contact loss =98.803821

Iron loss in core :7.896560

Armature copper loss :25.434783

Total losses : 370.906

Efficiency at F.L.:88.996832

END:
F:\IVEEE\89EEE04>

DESIGN SHEET SPECIFICATIONS

OUTPUT RATING (KW) :20.000000

SPEED IN RPM :1500.000000

VOLTAGE RATING :230.000000

CHOICE : Generator

TYPE : shunt

The no. of poles :4.000000

Power developed in armature:21.739130

Output coefficient=138.174492

speed in rps= 25.00000

Diameter Of Armature Core in m :0.215558

L / tou ratio:0.800000

Length Of Armature Core in m :0.135439

Number Of Ducts :2.000000

The Distance Between Two Ducts :7cm
Duct Width : 1 cm
Nett Length Of Iron in m:0.104482

Length Of Air Gap in m :0.001577

Peripheral Velocity in m/s :16.929913

Frequency of flux reversals :50.000000

No. of slots :24.000000
Slot pitch :6.000000
Depth Of Slot In m:0.032500
Line ct. in A: 86.9565
Current in armature (A): 85.4783
Field ct. in A :1.478261

Length of interpole in m: 0.102

Width of interpole in mm : 9.000

Length of air gap under interpole in m : 0.004

Inter pole ampere turns :10595.175116

Interpole turns :124.000000

COMMUTATOR DESIGN

Diameter of commutator in m :0.146580

No. of brushes :2

Width of brush:4.796809

USE CARBON BRUSHES
Area of brush :7.123188

Length of brush :0.742492

Length of commutator in cm :6.484985

Width of commutator segment :1.768723

Peripheral velocity :11.512341

SHUNT FIELD DESIGN
DEPTH OF FIELD WINDING : 0.035
AT PER UNIT HIEGTH OF FIELD :151900.000

C.S OF AREA OF SHUNTFIELD WIRE= 0.339

SHUNT FIELD turns = 820.000

ARMATURE WINDING DESIGN
TYPE OF WINDING TO BE USED IS WAVE WINDING

No. of parallel paths = 2
No. of armature conductors :432.000000

Conductors per slot :18.000000

Current density in A / mm^2 :5

Width of winding = 143.630

Width of slot in mm:= 0.144

Diameter of shaft in m:0.051057

Depth of slot in m:= 0.033

Total height of slot in cm :0.543617

Period of commutation in sec.:0.001667

Inter pole ampere turns :10595.175116

Interpole turns :124.000000

ASSUME PROGRESSIVE WINDING

Winding pitch :1

Front pitch :12.000000

Commutator pitch : 1

COMPUTATION OF LOSSES AND EFFICIENY

brush contact loss : 170.957

friction windage & brush contact loss =894.686458

Iron loss in core :56.447008

Armature copper loss :170.956522

Total losses : 1281.131

Efficiency at F.L.:93.979969

OUTPUT RATING (KW) :75.000000

SPEED IN RPM :1000.000000

VOLTAGE RATING :240.000000

CHOICE : Motor

TYPE : series
The no. of poles :4.000000

Power developed in armature:79.411765

Output coefficient=203.856724

speed in rps= 16.66667

Diameter Of Armature Core in m :0.333818

L / tou ratio:0.800000

Length Of Armature Core in m :0.209744

Number Of Ducts :3.000000

The Distance Between Two Ducts :7cm
Duct Width : 1 cm
Nett Length Of Iron in m:0.161803

Length Of Air Gap in m :0.002691

Peripheral Velocity in m/s :17.478697

Frequency of flux reversals :33.333333

No. of slots :36.000000
Slot pitch :9.000000
Depth Of Slot In m:0.042500
Line ct. in A: 312.5000
Current in armature (A): 308.2812
Field ct. in A :4.218750

```
Conductors per slot :8.000000
Current density  in  A / mm^2 :5
Width of winding =   299.089
Width of slot in mm:=     0.299
Diameter of shaft in m:0.090803
Depth of slot in m:=     0.043
Total height of slot in cm :1.479088
Period of commutation  in sec.:0.001667
Inter pole ampere turns :24964.953825
Interpole turns :81.000000


ASSUME PROGRESSIVE WINDING
Winding pitch :1
Front pitch :18.000000
Commutator pitch : 1
        COMPUTATION OF LOSSES AND EFFICIENY
brush contact loss :   616.562
friction  windage & brush contact loss =3303.671994
  Iron loss in core :176.875416
Armature copper loss :616.562500
Total losses :  5091.948
Efficiency at F.L.:93.642372
END:
F:\IVEEE\89EEE04>
```

Conclusion

CHAPTER - VII

CONCLUSION

A computer software has been developed for design of Dc machines. The program is written in Turbo-c language. The program has been tested for 3kw, 20kw and 75kw capacities on computer LAN system. The software can be used for design of dc machines of various capacities for 2kw to 2500 kw. The software is simple, more accurate,flexible and non-iterative. The software requires less memory space.

Further development of this program is possible by using C to AUTO-CAD interface adapter.

REFERENCES

1. A.K.SAWHNEY, "Acourse in Electrical machine design," Dhanpat Rai & Sons, 1990.

2. A.E.CLAYTON, "The performance and Design of Direct current machines", ELBS series, London 1962.

3. H.M.RAI, "Principles of Electrical Machine Design." Satya Prakashan, New Delhi, 1988.

4. FITZGERALS, KINDSLEY AND UMANS, "Electric Machinery " TATA McGRAW Hill Publications, 1989.

5. BYRON.S. GOTTFREID, "PROGRAMMING WITH C" McGRAW Hill Publications, 1990.

6. BERTOLINE, "Fundamentals of CAD" Galgotia Publications, 1987.

7. H.COTTON. "A course in Electrical technology", Kanna publications 1989.