COMPUTER

SOFTWARE FOR

DESIGN OF THREEPHASE

INDUCTION MOTORS

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CERTIFICATE

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This is the Bonafide Record of the Project Titled

COMPUTER SOFTWARE FOR DESIGN OF THREE PHASE
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INTERNAL EXAMINER   EXTERNAL EXAMINER

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C O N T E N T S

C H A P T E R - 1

PROLOGUE :

The computer Aided   Design (CAD) technique is one of the most recent trend in the field of machine design.   The hand calculation technique is a time consuming process and it could not synchronise with fast developing technology.   So inorder to keep in phase with the modern trend everyone has suritched over to computer aided design, which will occupy the foremost position in the further coming future.

In this project the authors have developed the CAD technique in the design or three phase induction motors.   The software developed incorporates a several design procedure for a three phase squirrel cage induction motor along with its performance evaluation, Optimization in design in a broad spectrum.

The performance evaluation encompasses the calculation of losses and efficiency computations.   The winding arrangements slot dimension and electrical characteristics have also been taken the foremost considerations in this project.   Morever the efficiency and the starting torque is considered as the constraints in this project.

Basic was used as the high level language, AURELEC ·₃8 bit computer having 254 K user memory area.

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C H A P T E R - II

I N T R O D U C T I O N

2.1 ENGINEERING DESIGN AND NEED OF COMPUTER :

An Engineering Design Problem is Usually stated as
follows. Devise, subject to certain constraints, a system or a process
to accompolish a specified task optimally. There are two kinds of
constraints on the Engineering designer. Of these, one set of constraints
applied to his problem solving procedure and the other set consists of such
items as cost and availability of material, equipment and manufacturing skills.
Design has been defined as both an art and a science. It is an art
because of the Uncertain factors and the decisions involving judgement
and experience and a science because these decisions cannot be arbitrary.

Analysis and synthesis are the two methods used in
designing. The final design is selected from a number of alternative designs
obtained from either of the foregoing two methods. Though this final
design may meet all the required specifications, it need not be an optimal one
as regard the cost of active material. The weight of active materials and
such other considerations. This additional optimality requirement can also
be achieved by formalating the design problem as a programming problem,
in which the cost or the weight or any such criterion forms the objective
function and the specifications of the system forms the constraints for
the problem.

In any Practical design, the number of variable

involved is so high that the hand calculations are impossible. The number of

constraints is also large and for these to be satisfied by the final

design, a lengthy iterative approach is required. It is only with the advent of

fast computers that the methods using the mathematical programming

techniques have become feasible for a practical design.

2.2 ADVANTAGES OF CAD

Litetarily it's a known fact that the electrical technology has developed amazingly in the recent past. But recently it has been chiped and shaped attractively to the final stage. The incoming of computers in the field of design is yet another land mark in the field of electrical technology.

The concept of computer aided Design, the modern trend in the design field, has emerged as a boon to the design engineers. It enables creations followed by rigorous testing of graphic models of designs without, involving the chores of making physical models.

The design procedure resides as a very general software which is user alterable. The user can alter the design as and when he wanted according to any given specifications. It is also kpossible for him to emphasis on any part of design according to the needs.

This vital advantage of flexibility in the design procedure is evident when modifications and alterations are sought after. Apart from the flexibility, the incredible speed with which the complex mathematical manipulations are done adds to the vers atality.

2.3 ADVANTAGES OF INDUCTION MOTORS

A full discussion of the design and behaviour of the various types of electric motor are available. Of all the types, the three phase induction motor is by for the most common and can be built in any size from a few watts up to several thousand KW. It has the following main advantages.

(i)   Its cost is low and is very reliable

(ii)   It has sufficiently high efficiency.

(iii)   It has reasonably good power factor

(iv)   It has a very simple and extremely rugged, almost unbreakable construction.

(v)   In normal operating conditions no brushes are needed hence frictional losses are reduced.

(vi)   It requires minimum of maintance

(vii)   It starts up from rest and needs no extra starting motor and has not to be synchonised.

(viii) Its starting arrangement is simple especially for squirrel cage type motor.

2.4 INDUSTRIAL APPLICATIONS:

i) Induction motor is the prime mover for ward-Leonard system

ii) Paper mills require speeds less than 200 rpm for beaters and large starting torque, slipring induction motor drives are used.

iii) In cement mill drives, slipring induction motors of 6.6 KV are widely used.

iv) In fan drives slip ring type motors variation generally between 1000 and 750 rpm.

v) In compressor drives squirrel cage induction motor canbe used and has speed variation between 1000 and 750 rpm.

vii) In textile mills the loom motors are three phase high torque squirrel cage induction motor.

viii) In spinning, 4 pole or 6 pole squirrel cage induction motor is used as a single speed motor.

viii) In coal mines the drives for compressors fans pumps conveyors and hoists are slip ring induction motor.

ix) Squirrel cage induction motors are the most widely used ones for most machine tool drives due to its simplicity reliability low cost and minimum maintenance requirements.

C H A P T E R - III

CONSTRUCTONAL DETAILS

INDRODUCTION:

A polyphase induction motor consists essentially of two major parts, the stator and the rotor. The construction of each one is basically a laminated core provided with slots which house windings. When one of the windings is excited with a.c. voltage, a rotating field is set up. this field produces an e.m.f. in the other winding by transformer action which is turn circulates current in the later if it is short circuited. The currents flowing in the second winding interact with the field produced by the first winding thereby producing a torque which is responsible for the rotation of the rotor.

STATOR:

This is the stationary part of an induction motor. It is a cylindrical structure, built up of dynamo grade laminations. Motors having outside diameters of the stator core upto about one metre use one-piece core laminations.

For large sized motors, the stator cores are made of segmental laminations. This is done in order to avoid wasting of steel

from the centre of the rotor and from theoutside corners of the stator with the cores made up of segments assembled in ring form. For quick assembly of stator core, maximum chord of segment should not be less than 0.37 m. It is necessary to determine the total number of dovetails for fixing the segments to the frame and also to determine the location and number of dovetails per segment.

The total number of segments is chosen in such a way as to provide an equal number of joints in the core flux paths of alternating poles. this resultant flux produces an alternating voltage between the two ends of the shaft, giving rise to shaft currents which in turn may cause damage of bearings, unless the bearings are insulated from the end shields.

STATOR FRAMES:

Frames of electrical machines are structures in which stator core is assembled. They serve four distinct purposes:

i) They enclose the core and windings

ii) They shield the live and moving machine parts from human contact and from injury caused by intruding objects or weather exposure.

iii) They transmit the torque to the machine supports, and are therefore designed to withstand twisting forces and shocks.

iv) They serve as ventilating housing or means of guiding the coolant into effective channels.

A great variety of designs is employed to meet the above requirements, and to adapt machines to particular service conditions.

For induction motors the frame shoud be strong and rigid both during construction and after assemblyof the machine. This is because the length of air gap is very small and if the frame is not rigid, the rotor will not remain concentric with stator giving rise to unbalanced magnetic pull.

The frames of large size machines are fabricated by welding steel plates. The advantage of fabrication is its adaptability to new designs and modifications. Frames of small machines are made as a single unit. The frames of totally enclosed machines are provided with axial fins in order to increase the heat dissipating surface.

Medium sized machines (ie machines whose stator core diameter exceeds 1 m but is not more than 2.5 to 3.0 m) are provided with radial ventilating ducts.

ROTOR:

Like Stator, the rotor laminations are punched as a single unit in the case of small machines while in larger machines the laminations are segmented.

Rotor cores of small machines are often put on the shaft directly and keyed to it for transfer of torque. In order to provide paths for ventilating air, radial and axial ducts are used. the number of radial ventilating ducts provided in the rotor is equal to that in the stator. The segmental laminations are fixed to rotor spider. This comprises of a shaft with arms and stiffners.

STATOR WINDINGS:

The windings used for induction motor stators, double layer lap type winding with diamond shaped coils is generally used. For small motors single layer mush windings are used.

The three phases of the winding canbe connected in either star or delta depending upon starting methods employed. the squirrel cage motors are usually started by star delta starters and therefore their stators are designed for delta connection. The would rotor motors are started by putting resistance in rotor circuit.

SHAFTS AND BEARINGS:

The air gap of induction motor is made as small as possible. Therefore the shaft is made short and stiff in order that the rotor may not have any significant deflection, as even a small deflection would create large irregularities in the air gap which would lead to production of an unbalanced magnetic pull.

C H A P T E R - IV

DESIGN   ASPECTS

OUTPUT EQUATION:

The output equation for ac machines is :

KVA input $Q = C_o D^2 L$

Output coefficient $= C_o = 11 K_W B_{av} ac \times 10^{-3}$

$D^2L = /C_o$

KVA input $= K_W / Cos$)

If the rating of an inductio motor is given in horse

power then the KVA input is:

$$Q = h.P \times \frac{0.746}{Cos}$$

The horsepower, speed, powerfactor and efficiency

of an machine are specified. therefore in order to calculate the value

of D^2L, We must evaluate the output coefficient, the value of output coefficient

depends upon the choise of electric and magnetic loadings (ie) values of

ac and B_{av},

CHOICE OF AVERAGE FLUX DENSITY IN AIR GAP:

Choice of average flux density in the air gap depends

upon on the following factors.

i) POWERFACTOR, II) IRON LOSS iii) OVER LOAD CAPACITY

For 50 Hz machines of normal design the value of B_{AV} lies between 0.3 and 0.6 Wb/m². for machines used in cranes, rolling mills etc., where a large overload capacity is required, a value of 0.65 Wb/m². may be used.

PERIPHERAL SPEED:

Standard constructions can generally used for peripheral speeds upto 60 m/sec. For a normal design, the diameter should be so chosen that the peripheral speed does not exceed about 30 M/s.

VENTILATING DUCTS:

The stator is provided with radial ventilating ducts if the core length exceeds 100 to 125 mm.

STATOR WINDNG:

Double layer lap type winding with diamond shaped coils is generally used for stators. Small motors with a small motors with a small number of slots and having a large number of turns per phase may be used singlelayer mush windings.

TURNS PER PHASE:

Flux per pole $\phi_m = B_{av} \; L = B_{av} \times \Pi \, DL/P$

Stator voltage per phase $E_s = 4.44 \times f \; \phi_m T_S \; KWS$

Where,

T_s = number of turns per pahse in stator

KWS = Stator winding factor.

CHOICE OF AMPERE CONDUCTORS PER METRE:

Choice of ampere conductors per metre depends upon the following factors.

i) Copper loss and temperature rise   ii) Voltage
iii) Overload capacity.

MAIN DIMENSIONS:

The ratio of core length to polepitch for various design feature is

Minimum cost - 1.5 to 2

Good power factor - 1.0 to 1.25

Good efficiency - 1.5

Good overall design - 1

The winding factor may be initially assumed as 0.955 which is the value of winding factor for infinitely distributed winding with full pitch coils.

$$\text{Stators turns per phase} = E_S / 4.44 \times f \quad KWS$$

STATOR CONDUCTORS:

The current density in the stator windings is usually between 3 to 5 A / mm²

$$\text{Stator current per phase} = E_S = / 3E_S$$

$$\text{Area of each stator conductor} = a_S = E_S /$$

- Current density in stator conductors.

NUMBER OF STATOR SLOTS:

The following factors are considered in selecting the number of stator slots.

i) Tooth Pulsation Loss:

Tooth pulsation losses and noise canbe minimised by using large number of narrow slots.

ii) Leakage reactance:

With a large number of slots, the machine has higher overload capacity.

iii) Magnetising current and iron loss:

The use of larger number of slots may result in excessive flux density in teeth giving rise to higher magnetising current and higher iron loss.

iv) Cost:

With larger number of slots there are larger number of coils to wind, insulate and instal involving higher costs

The stator slot pitch $= Y_{SS} = \dfrac{\text{gap surface}}{\text{total number of stator slots}}$

$$= \Pi \, D / S_S$$

Where S_S = number of stator slots

Total number of stator conductors $= 3 \times 2 \quad T_s = 6 \, T_s$

Conductors per stator slot $= Z_{ss} = 6 \, T_s / S_S$

AREA OF STATOR SLOTS:

When the number of conductors per slot has been otabined, an approximate area of the slot can be calculated.

Approximate area of each slot = copper area per slot/ space factor

$$= \frac{Z_{ss} \, x a_s}{\text{Space factor}}$$

The tooth widthand the slot width at the gap surface should be approximately equal.

From the above we conclude that the length of air gap in an induction machine should be as small as the mechanically possible in order to keep down the magnetising current and to improve powerfactor this is a major consideration. But if a higher overload capacity, better loading, reduction in noise or reduction in unbalance magnetic pull is important, large air gap lengths should be used.

LENGTH OF MEAN TURN:

The approximate length of mean turn of the winding on induction motor stators for use an voltage upot 650 V may be calculated from the following empirical relationship.

Length of mean turn of stator = L_{mts} = 2L+2.3   +0.24

with values of L and   are expressed in mts.

STATOR TEETH:

The dimension of the slot determine the value of flux density in the teeth. A high value of flux density in the teeth is not desirable, as it leads to a higher iron loss and a greater magnetising mmf. The maximum value of Bts, the mean flux density in stator teeth should not exceed 1. to 1.7 Wb/m².

Minimum tooth area per pole $= \phi m / 1.7$

Tooth area per pole = number of slots per pole x net iron length x width of tooth

$$= (S_s/p) \times Li \times Wts.$$

or minimum width of stator tooth,

$$(Wts) \; min = \phi_m / 1.7 \times (S_s/p) \; Li$$

The minimum width of stator teeth is near the gap surface.

STATOR CORE:

The flux density in the core shoud not exceed about 1.5 wb/m². generally it lies between 1.2 to 1.4 wb/m².

Flux in the stator core $= \phi_m /2$

Area of stator core $= \dfrac{\text{Flux through core}}{\text{Flux density in stator core}} = \phi_m /2Bcs$

Area of stator core = Li x dcs

Where   dcs = depth of stator core

Thus Li x dcs = ϕ_m / 2Bcs

$$dcs = \phi_m / 2Bcs \times Li$$

The outside diameter of stator laminations,

D_o = D + 2 (depth of stator slots + depth of core)

= D + 2 dss + 2 dcs.

DESIGN OF SQUIRREL CAGE ROTOR

NUMBER OF ROTOR SLOTS:

The selection of number of rotor slots in squirrel cage motors is very important and a considerable attention should be paid to select a suitable value. This is because with certain combination of stator and rotor slots the machine may refuse to start or may crawl at some sub synchronous speed. In some cases severe vibtrations may be set up generating excessive noise. The effects are produced by harmonic fields. The haromonic fields are due to:

     i) Windings

     ii) Slottings

     iii) Saturation

     iv) Irregularities in the air gap.

AREA OF ROTOR BARS:

The performance of an induction motor is greatly influenced by the resistance of rotor. A motor designed with high rotor resistance has the advantage that it has a high starting torque. However a rotor with a high resistance has the dis advantage that its $I^2 R$ loss is greater and therefore its efficiency is lower under running conditions.

The value of rotor resistance depends upon the current density used for rotor conductors, the higher the current density, the lower is the conductor area and greater the resitance. Therefore, a rotor

designed with a high value of current density results in high starting torque and a lower efficiency for the machine.

The rotor resitance is the sum of the resistance of the bars and the end rings. The cross-section of the bars and the end rings must be so selected that a proper value of rotor resistance is obtained. ie, a value of rotor resitance which meets both the requirements of starting torque as well as the efficiency.

It is desirable to have a compromise between a high resistance rotor which gives a good starting torque and a low resistance rotor which gives a high value of efficiency under running conditions.

Current density in the rotor bars may be taken between 4 to 7 A/mm².

Area of each bar $a_b = I_b/ \delta_b$ mm²

SHAPEANDSIZE OF ROTOR SLOTS:

The rotor slots for squirrel cage rotor may either be closed or semi - enclosed types.

Closed slots are preferred for small size machines because the reluctance of the air gap is not large owing to absence of slots opening. This gives a reduced value of magnetising current. As the surface of the rotor is smooth, the operation of machine is quieter. the biggest

advantage is that the leakage reactance with closed slots is large and therefore the current at starting can be limited. this is very useful in the case of machines which are started with direct on line starters. But the disadvantage is that the increased value of reactance results in reduction of over load capacity. A semi - enclosed slot gives a better over load capacity.

The rectangular shaped bars and slots are generally preferred to circular bars and slots as the higher leakage reactance of the lower part of the rectangular bars, during starting, forces most of the current through the top of the bar. this increases the rotor resistance at starting and improves the starting torque. Deep slots, however, given an increased leakage reactance and a high flux density the root of the teeth.

ROTOR SLOT INSULATION:

No insulation is used between bars and rotor core. A clearance of 0.15 to 0.4 mm can be left between rotor bars and the core depending upon whether slots are skewed or not. Higher clearances have to be left for the skewed slots.

DESIGN OF END RINGS:

END RING CURRENT:

The stator winding is a three phase distributed winding and thus produces a revolving field. this field may be considered as sinusoid-ally distributed in space as the harmonics in most cases are small and produce

only secondary effects. this revolving field produces emfs of fundamental frequencyin the bars, shows the magnitude of emfs in the bars and if the bars are assumed to be infinitely distributed, the distribution of emfs canbe considered as sinusoidal in the bars over a pole pitch. these emfs produced in the bars would circulate currents. If the resistance of end rings is negligible as compared with that of the bars, the resistance coming in each current path is the resistance of two bars. thus the current which the bars carry would be proportional to their instantaneous emfs which in turn depend uponthe position of the bars in the magnetic field. thus the wave which represents the emf would represent the bar current also, shows the wave representing currents in bars.

ROTOR TEETH:

The width of the rotor slot should be suchthat the flux density in the rotor teeth does not exceed about 1.7 Wb/m^2. The maximum flux density for rotor teeth occurs at their root as their section is minimum there.

Minimum width of rotor teeth

$$Wtr \ (min) \ = \ \emptyset_m \ / \ 1.7 \ x \ (S_r/p) \ X \ Li$$

Minimum dwidth of tooth actually provided Wtr = rotor slot pitch at the root slot width $= \ \dfrac{II \ (Dr \ - \ 2d_{sr} \qquad) \quad w_{sr}}{S_r}$

Where

d_{sr} = depth of rotor slot

and W_{sr} = width of rotor slot

ROTORCORE:

The flux density in the rotor core is generally equal
to stator core density.

Depth of rotor core dcr ϕ_m /2 x Bcr x Li

Where,

Bcr = flux densty in the rotor core.

Inside diameter of rotor lamination

D_i = D_r - 2 (Dsr + dcr)

The flux density in rotor teeth and core can be taken
slightly higher than those in the stator teeth and core.

C H A P T E R - V

DESCRIPTION OF THE PROGRAM :

Engineers and scientists make use of the high-speed computing capability of computers to solve their complex research and design problems. Many culculations that were previously beyound contemplation have now become possible. Computer aided design and computer aided manufacture are becoming popular among the large industrial establishments.

A set of programs that are run in a computer is called software. The functioning of a computer is controlled by a set of instructions. A complete set of such instructions is called a computer program. The language which is used in the communication of computer instructions is known as programming language. Many high level languages have been developed. The choice of a suitable language depends on the knowledge of the programmer, modes of the computer, problem to be solved etc. Nowadays in many enginering applications BASIC is used.

BASIC stands for Begineer's All-purpose symbolic instruction code, it is an extremely powerful and useful language. The BASIC language was designed tube conversational right from start. This can put the programmer into direct communication with the computer. While running the program, the programmer can ask for the results at intermediate points and check for the correctness of his program logic without having to wait for the computer to reach the end of program.

The functions of BASIC Statements involve:

1.   Getting the data into the computer memory

2.   Performing certain valculations using the supplied data.

3.   Making decisions based on certain conditions.

4.   Transferring the results from the computer memory to an output device.

5.   Telling the computer to stop running the program.

Each line in the program is called a program statement and is given a separate line number. The statements are executed in the increasing order of line numbers. The END statement which terminates the program has the highest line number. The words REM, PRINT, INPUT, READ, DATA, etc..... are known as key words IF .....THEN, FOR NEXT, GO.TO, GOSUB, RETURN, etc... are known as control statements.

PRINT, PRINT, ... USING, READ ....DATA..... RESTORE are known as Input/Output statements which control the more movement of data to or from the terminal.

CHAPTER - VI

ALGORITHM

STEP 1

For design of IM the input requirements supply voltage, supply frequency, rating of the machine, speed, efficiency, powerfactor stator winding factor, specific magnetic loading specific electric loading and number of phases.

STEP 2

Main dimensions were obtained from the output equvation.

$$C_0 = 11 \text{ kw } B_{av} \text{ ac } \times 10^{-3}$$

$$D^2L = \frac{Q}{C_0 \ x}$$

Overall diameter can be selected from the corresponding values of nominal conductor diameter and medium covering.

STEP 3

Number of turns per phase $= T_s = \dfrac{V_{phase}}{4.44 \times f \times \phi_m K_{ws}}$

Stator winding factor $= K_d = \dfrac{\text{Sin}\,(\,3\,/2 \times \text{II}\,/\,180\,)}{3\,\sin\,(\,/2)\times \text{II}\,/\,180}$

$$K_p = \text{Cos}\,(\,/2 \times \text{II}\,/\,180)$$

$K_{ws} = K_p \times K_d$

Stator current /phase $= I_s = \dfrac{Q}{3\,E_{,s}}$

Area of each conductors $= as = \dfrac{Is}{ds}$

Total number of conductors $= 3 \times 2\,T_s$

Conductors per stator slot $= Z_{ss} = 6T_s\,/S_6$

Area of each slot $= Z_{ss} \times a_s$ / space factor

STEP:4

(Design of squirrel cage rotor)

Current density in each rotor $= 4 - 7\ A\ /mm^2$

Area of each bar $= a_v = I_b/\quad b$

Shape and size of rotor slots are selected according to the overload capacity.

STEP : 5

Minimum width of rotor teeth $= \quad \emptyset_m\,/\,1.7 \times (S_r/p) \times Li$

Minimum width actually provided $= \dfrac{\text{II}\,(D_r - 2dS_r) - W_{sr}}{S_r}$

D_{sr} depth of rotor slot

W_{sr} Width of rotor slot

STEP : 6 (Design of Rotor core)

Depth of rotor core $d_{cr} = \emptyset_m / 2 \times B_{cr} \times l_i$

Inside Dia of rotor lamination $= D_r = 2(d_{sr} + d_{cr})$

STEP :7 (Operating characteristics)

mmf for air gap $AT_{\overline{g}} = 800000 \times B_g \, 60 \, Kg \quad l_g$

$$B_{g60} = 1.36 \, B_{av}$$

Flux density at 1/3 height of tooth from narrow end

$$B_{ts \, 1/3} = \emptyset_m / S_{S/P}) \times l_i \times W_{ts \, 1/3}$$

$W_{ts1/3} =$ width of stator at 1/3 height from narrow end

$$W_{ts \, 1/3} = \text{II} \, \frac{(D + 2dss/3)}{S_s} - W_{ss}$$

mmf for stator teeth $= AT_{ts} = at_{ts} \times l_{ss}$

mmf for rotor teeth $B_{tr \, 1/3} = \emptyset_m / S_{r/p}) \times L_i \times W_{tr \, 1/3}$

$$W_{tr \, 1/3} = \text{II} \, \frac{(D_r - 4dsr/3)}{S_r} - W_{sr}$$

mmf required for rotor teeth

$AT_r = at_{sr} \times l_r$

mmf for stator core $= \text{II} \, \dfrac{(D + 2 \, d_{ss} + d_{cr})}{3P}$

mmf for rotor core $= \dfrac{\amalg (D_r - 2d_{sr} - d_{cr})}{3P}$

Total mm + rotor core $AT_{cr} = at_{cr} \times l_{cr}$

Total magnetising mmf per pole for B_{60}

$AT_{60} = AT_g + AT_{ts} + AT_{tr} + AT_{cs} + AT_{cr}$

Magnetising current per phase

$I_m = \dfrac{0.427 \ P \ A \ T_{60}}{KWS \ T_s}$

STEP : 8

Loss component of no load current $= I_l$

$$= \dfrac{\text{total no load loss}}{3 \times \text{voltage per phase}}$$

No load current $= I_o$

$$I_o = \sqrt{I_m{}^2 + I_l{}^2}$$

No load poer factor $= \text{Cos} \ \emptyset \quad F_l / I_o$

FLOW CHART

READ IN
SPECIFICATIONS, CONSTRAINTS,
OUTPUT REQUIREMENTS,
INTIAL MACHINE
DIMENSIONS, WINDING
PARAMETERS, AND
OBJECTIVE FUNCTION

FORMULATE
EQUIVALENT CIRCUIT
AND ANALYZE
PERFORMANCE

ARE
SPECIFIED CONSTRAINT
SATISFIED?

CHANGE MACHINE
DIMENSIONS AND
WINDING PARAMETERS

IS
OBJECTIVE FUNCTION
MINIMISED?

PRINT ALL DATA AND
MACHINE PEREFORMANCE
CHARACTERISTICS.

STOP

END

MAIN DIMENSION CALCULATIONS

START   A

READ

(i)   POWER IN KW (KW)
(ii) APPLIED VOLTAGE IN VOLTS (V)
(iii) FREQUENCY IN HERTZ (F)
(iv) PHASE (PH)
(v)   SYNCHRONOUS SPEED IN RPM (N)
(vi) FULL LOAD EFFICIENCY (E)
(vii) POWER FACTOR (C)
(viii)SPECIFIC MAGNETIC LOADING (BAV)
(ix) SPECIFIC ELECTRIC LOADING (AC)

CALCULATION OF

(i)   SYNCHRONOUS SPEED IN RPS (N_s)

(ii)   NO. OF POLES (P)
(iii) KVA INPUT (Q)
(iv)   OUTPUT COEFFICIENT (C_o)

READ L/T RATIO FOR
GOOD EFFICIENCY
(LT)

CALCULATION OF

(i) LENGTH (L)
(ii) DIAMETER (D)

READ WIDTH OF DUCT (W_d)

$$L \quad 10 \times 10^{-3}$$

READ
NUMBER OF
DUCT
$n_d = 2$

READ
NUMBER OF
DUCT
$n_d = 1$

CALCULATION
OF NET
IRON
LENGTH
(Li)

STATOR DESIGN

CALCULATE

    (i)   FLUX PER POLE (ϕm)
    (ii)   STATOR TURNS PER PHASE (Ts)

READ

    (i)   SLOTS / POLE / PHASE (SPP)
    (ii)   PITCH FACTOR (Kp)

CALCULATE

    (i)   NO. OF STATOR SLOTS (SS)
    (ii)   STATOR CONDUCTORS (TSC)
    (iii) CONDUCTORS PER SLOT (2ss)
    (iv)   TOTAL NO OF TURNS (TSC1)
    (v)   TOTAL NO OF TURNS / PHASE (TS1)

IS
(TSC1 TS1) 10

TURNS / PHASE = TS1   CHANGE
                                         BAV

                                                   GOTO B

CALCULATE COIL SPAN (CS)

IS
IS AN EVEN
INTEGER?

MAKE Cs AN ADD

USE SINGLE LAYER
MUSH WINDING

CALCULATE

    (i)   DISTRIBUTION FACTOR (Kd)
    (ii)   STATOR WINDING FACTOR (KWS)

SC

(i) WIDTH OF SLOT
   = Wss   CHANGE Wss
(ii) DEPTH OF SLOT   AND Dss
    = Dss

CALCULATE
LENGTH OF MEAN TURN
(Lmt)

CALCULATE

(i)   AREA OF STATOR
      CORE (ACS)
(ii) DEPTH OF STATOR
      CORE (dcs)
(iii) OUTER DIAMETER OF
      STATOR LAMINATIONS

RA

ROTOR DESIGN

CALCULATE

(i)   LENGTH OF AIRGAP (Lg)
(ii) DIAMETER OF ROTOR (Dr)
(iii) NUMBER OF ROTOR SLOTS (sr)
(iv) ROTOR SLOT PITCH (Ysr)

CALCULATE

       (i)   CURRENT IN EACH BAR (ib)
       (ii)   AREA OF EACH BAR (ab)

READ

       (i)   INSULATION THICKNESS
       (ii)   WEDGE AND LIP THICKNESS

CALCULATE

       (i)   WIDTH OF ROTOR SLOT (Wsr)
       (ii)   DEPTH OF ROTOR SLOT (Dsr)

CALCULATE THE FLUX DENSITY AT
THE ROOT OF THE TOOTH (B2)

             IS
        B2   1.2

CHANGE
dsr

CALCULATE

       (i)   LENGTH OF EACH BAR (Lb)
       (ii)   RESISTANCE OF EACH BAR
                         (Rb)
       (ii)   TOTAL COPPER lOSSES
                 IN THE BARS

READ

      CURRENT DENSITY
      IN END RING (ie)

CALCULATE

      (i)   AREA OF END RING (ae)
      (ii)   DEPTH OF END RING
      (iii)   THICKNESS OF END RING
      (iv)   OUTER DIAMETER
               OF END RING
      (v)   INNER DIAMETER
               OF END RING
      (vi)   MEAN DIAMETER
               OF END RING

CALCULATE

      (i)   RESISTANCE OF EACH
               END RING
      (ii)   COPPER LOSS IN TWO
               END RINGS

CALCULATE

      (i)   TOTAL COPPER LOSS
      (ii)   FULL LOAD SLIP

TAKE

    DEPTH OF ROTOR CORE
    = DEPTH OF STATOR CORE

CALCULATE

    INNER DIAMETER OF
    ROTOR LAMINATIONS

CALCULATION OF NOLOAD CURRENT

CALCULATE

      (i)   MAGNETISING CURRENT
      (ii)   LOSS COMPONENT
            CURRENTS

CALCULATION OF LOSSES

      (i)   STATOR COPPER LOSSES
      (ii)   ROTOR COPPER LOSS
      (iii) IRON LOSS
      (iv) TOTAL LOSSES

CALCULATE
      TEMPARATURE RISE (Q)

        IS
     $\emptyset$ 50°

CALCULATE
EFFICIENCY

        IF   CHANGE
    GIVEN VALUE   Bav, AC

print

(i)	MAIN DIAMENSIONS
(ii)	NUMBER OF STATOR SLOTS
(iii)	STATOR CONDUCTORS
(iv)	CONDUCTORS / SLOT
(v)	TOTAL NO OF TURNS
(vi)	TOTAL NO OF TURNS / PHASE
(vii)	AREA OF STATOR CONDUCTOR
(viii)	DIAMETER OF STATOR CONDUCTOR
(ix)	WIDTH OF SLOT
(x)	DEPTH OF SLOT
(xi)	TOOTH WIDTH AT
(xii)	AREA OF STATOR CORE
(xiii)	DEPTH OF STATOR CORE
(xiv)	OUTER DIAMETER OF STATOR LAMINATIONS
(xv)	LENGTH OF MEAN TURN
(xvi)	LENGTH OF AIR GAP
(xvii)	DIAMETER OF ROTOR
(xviii)	NUMBER OF ROTOR SLOTS
(xix)	ROTOR SLOT PITCH
(xx)	WIDTH OF ROTOR SLOT
(xxi)	DEPTH OF ROTOR SLOT
(xxii)	TOTAL COPPER LOSSES

PRINT

(i)	AREA OF END RING
(ii)	DEPTH OF END RING
(iii)	THICKNESS OF END RING
(iv)	INNER DIAMETER OF END RING
(v)	MEAN DIAMETER OF END RING
(vi)	NO LOAD CURRENTS
(vii)	TEMPARATURE RISE

STOP

END

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```
10 REM ***********************************************************
20 REM    COMPUTER SOFTWARE FOR DESIGN OF THREE PHASE INDUCTION MOTORS
30 REM***********************************************************
40 DIM DS1(100),ODC(100)
50 DIM FLDT(1000),CDPLOS(1000)
60 DIM DIORC(100),ODRC(100)
70 DIM FD1(1000),STPW(1000)
80 REM***********************************************************
90 REM           CALCULATION OF MAIN DIMENSIONS
100 REM***********************************************************
110 INPUT "SUPPLY VOLTAGE=";V
120 INPUT "SUPPLY FREQUENCY=";F
130 INPUT "RATING OF THE MACHINE=";P
140 INPUT "SPEED OF THE ROTOR =";N
150 INPUT "EFFICIENCY OF THE MOTOR=";E
160 INPUT "POWER FACTOR=";C
170 INPUT "STATOR WINDING FACTOR=";KW
180 INPUT "SPECIFIC ELECTRIC LOADING=";AC
190 INPUT "SPECIFIC MAGNETIC LOADING=";BAV
200 INPUT "NUMBER OF PHASES=";PH
210 NS=N/60
220 P=INT(2*F/NS)
230 J=P/(E*C)
240 CO=11*BAV*AC*KW*10^(-3)
250 DSL=J/(CO*NS)
260 LT=1.6*3.14/P
270 D=(DSL/LT)^(1/3)
280 L=LT*D
290 TP=3.14*D/P
300 YT=P
310 WD=.61
320 IF YT=1 THEN 350
331 LI=KW*(L-WD)
340 GOTO 360
350 LI=KW*(L-2*WD)
360 PRINT "LENGTH=";L;"mt"
370 PRINT "DIAMETER=";D;"mt"
380 PRINT "GROSS LENGTH=";LI;"mt"
390 REM
400 REM***********************************************************
410 REM              STATOR DESIGN
420 REM***********************************************************
430 FLUX=BAV*TP*L
440 TS=INT(V/(4.44*F*FLUX*KW))
450 PRINT "NO OF TURNS=";TS
460 SPP=P/2
470 SS=SPP*PH*P
480 YSS=3.14*D/SS
490 TSC=6*TS
500 TSS=INT(TSC/SS)
```

```
510 TE01=200*K6
520 T01=TE01/(G*N)
530 PRINT "TURNS PER PHASE=";T01
540 PRINT "WUSH WINDING IS USED AND"
550 PRINT "PARALLEL SIDED SLOTS ARE USED"
560 C9=S6/P
570 KC01=INT(C9/2)
580 KC02=KC01*2
590 IF KC02=C9 THEN 620
600 C91=C9-1
610 GOTO 640
620 C91=C9
630 PRINT "C91=";C91
640 P8=C9/(P*N)
650 A9=P*180/S6
660 PSP=120/A9
670 GOSUB 740
680 PRINT "STATOR WINDING FACTOR=";KW8
690 PRINT "Y PHASE STARTS";PSP;"SLOTS AWAY FROM R PHASE"
700 PRINT "B PHASE STARTS";PSP;"SLOTS AWAY FROM Y PHASE"
710 GOTO 860
720 REM
730 REM************************************************************
740 REM            CALCULATION OF STATOR WINDING FACTOR
750 REM************************************************************
760 ALPH=A9
770 LN1=SIN((SPP*ALPH/2)*3.14/180)
780 LN2=SIN(ALPH/2*3.14/180)
790 KD=LN1/(SPP*LN2)
800 IF KC02<>C9 THEN 820
810 KP=COS(ALPH/2*3.14/180)
820 KP=1
830 KW8=KP*KD
840 PRINT "KW8=";KW8
850 RETURN
860 REM
870 REM************************************************************
880 REM            CALCULATION OF CONDUCTOR SIZE
890 REM************************************************************
900 REM
910 I9=Q*1000/(3*V)
920 PRINT "ASSUME CURRENT DENSITY OF 4 A PER Sq.mm"
930 CD=4
940 A9R=I9/CD
950 D9=SQR(A9R*4/3.14)
960 IF D9<1.5 THEN 1040
970 D911=D9/2
980 PRINT "USE TWO CONDUCTORS IN PARALLEL OF DIAMETER =";D911;"mm"
990 A9R1=2*3.14/4*D911^2
1000 GOTO 1040
```

```
1010 DC11=D9
1020 PRINT "USE ONE CONDUCTOR OF DIAMETER=";DC11;"M"
1030 AC01=3.14/4*DC11^2
1040 PRINT "DIAMETER OF BARE CONDUCTOR=";DC11;"M"
1050 PRINT "AREA OF CONDUCTOR PROVIDED=";AC01;"SQ.M"
1060 REM
1070 REM********************************** OVERALL DIA CALCULATION
1080 REM
1090 REM**********************************
1100 GOSUB 1130
1110 PRINT "OVERALL DIAMETER OF THE CONDUCTOR =";ODC1;"M"
1120 GOTO 1400
1130 FOR I=1 TO 75
1140 READ DC1(I),ODC(I)
1150 NEXT I
1160 DATA 0,.050,.065,.06,.078,.071,.092,.08,.105,.090,.115
1170 DATA .1,.128,.112,.148,.125,.159,.137,.169,.14,.174
1180 DATA .15,.194,.16,.199,.17,.211,.18,.223,.195,.239
1190 DATA .2,.247,.213,.258,.224,.272,.234,.281,.25,.301
1200 DATA .258,.308,.265,.317,.28,.334,.3,.354,.307,.360
1210 DATA .315,.370,.325,.393,.355,.415,.375,.450,.4,.445
1220 DATA .425,.493,.442,.501,.475,.546,.5,.571,.53,.602
1230 DATA .56,.635,.6,.677,.63,.707,.67,.75,.71,.791
1240 DATA .73,.811,.75,.831,.80,.884,.85,.935,.905,1.014
1250 DATA .95,1.041,1,1.095,1.06,1.155,1.12,1.215,1.18,1.279,1.25,1.35
1260 DATA 1.32,1.42,1.4,1.505,1.5,1.605,1.4,1.7,1.7,1.81
1270 DATA 1.8,1.915,1.9,2.015,2.06,2.18,2.12,2.241,2.24,2.36
1280 DATA 2.36,2.498,2.5,2.63,2.65,2.795,2.8,2.935,2.9,3.04
1290 DATA 3,3.14,3.15,3.295,3.25,3.395,3.35,3.502,3.45,3.6
1300 DATA 3.55,3.7,3.65,3.8,3.75,3.902,4,4.155
1310 FOR I=1 TO 75
1320 IF DC11=DC1(I) THEN 1370
1330 IF DC11<DC1(I) THEN 1350
1340 NEXT I
1350 ODC1=ODC(I)-(ODC(I)-ODC(I-1))/(DC1(I)-DC1(I-1))*(DC1(I)-DC11)
1360 GOTO 1380
1370 ODC1=ODC(I)
1380 RETURN
1390 REM**********************************
1400 REM              CALCULATION OF SLOT DIMENSION
1410 REM**********************************
1420 IF DС1=D9 THEN 1450
1430 NWS=2*ZSS
1440 GOTO 1460
1450 NWS=ZSS
1460 NCW=1
1470 IF (NWS-INT(NWS/NCW)*NCW=0) THEN 1500
1480 NCW=NCW+1
1490 GOTO 1470
1500 NCD=NWS/NCW
```

```
1510 WSS=NCW*ODC1*10^(-3)+2*10^(-3)
1520 DSS=NCD*ODC1*10^(-3)+2*10^(-3)
1530 TAPP=CS/P*LI*WSS
1540 WFD=FLUX/TAPP
1550 WWST=FLUX/(1.7*CS/P*LI)
1560 IF WFD<=1.7 THEN 1580
1570 GOTO 1480
1580 IF WSS>=WWST THEN 1600
1590 GOTO 1400
1600 PRINT "WIDTH OF THE STATOR SLOT=";WSS;"mt"
1610 PRINT "DEPTH OF THE STATOR SLOT=";DSS;"mt"
1620 LMT=2*L+2.3*TA+.24
1630 PRINT "LENGTH OF THE MEAN TURN=";LMT;"mt"
1640 REM*********************************************************
1650 REM                    STATOR CORE DESIGN
1660 REM*********************************************************
1670 FC=FLUX/2
1680 FD=1.4
1690 ACS=FC/FD
1700 DCS=ACS/(LI)
1710 DO=D+2*(DSS+DCS)
1720 PRINT "STATOR LAMINATION OUTER DIAMETER=";DO;"mt"
1730 REM*********************************************************
1740 REM                    ROTOR DESIGN
1750 REM*********************************************************
1760 LG=.2+2*SQR(D*L)
1770 DR=D-2*LG*10^(-3)
1780 PRINT "LENGTH OF THE AIR GAP=";LG;"mm"
1790 PRINT "ROTOR DIAMETER=";DR;"mt"
1800 REM*********************************************************
1810 REM                    ROTOR SLOT DESIGN
1820 REM*********************************************************
1830 SR=SS+P/2
1840 YSR=3.14*DR/SR
1850 IB=(2*SPP*KWS*TS*IS*C)/SR
1860 PRINT "ASSUME CURRENT DENSITY OF 5A per sqmm"
1870 RCD=5
1880 AB=INT(IB/RCD)
1890 WB1=1
1900 IF (AB-INT(AB/WB1)*WB1=0) THEN 1930
1910 WB1=WB1+1
1920 GOTO 1900
1930 DB1=AB/WB1
1940 WRS=WB1+.15
1950 DRS=DB1+.15
1960 ARP=WRS*DRS
1970 PRINT "WIDTH OF THE ROTOR SLOT=";WRS;"mt"
1980 YSSR=3.14*(DR-2*DRS*10^(-3))/SR
1990 WTR=YSSR-WRS*10^(-3)
2000 FDRT=FLUX*P/(SR*LI*TR)
```

```
2010 IF FDRT<=1.7 THEN 2030
2020 GOTO 1910
2030 PRINT "WIDTH OF THE ROTOR SLOT =";WRS;"mm"
2040 PRINT "DEPTH OF THE ROTOR SLOT =";DRC;"mm"
2050 LB=L+2*20*10^(-3)+10^(-3)
2060 PRINT "LENGTH OF EACH BAR=";LB;"mm"
2070 RHO=.021
2080 RB=RHO*LB/QBR
2090 TCB=SR*IB^2*RB
2100 PRINT "TOTAL COPPER LOSS IN BARS=";TCB;"Watts"
2110 REM******************************************************
2120 REM                       END RING DESIGN
2130 REM******************************************************
2140 IE=SR*IB/(3.14*P)
2150 QE=INT(IE/5)
2160 PRINT "THICK OF THE END RING=10mm"
2170 TE=10
2180 DE=QE/TE
2190 DOE=DR-2*DRS*10^(-3)
2200 DIE=DOE-2*DE*10^(-3)
2210 MDE=(DOE+DIE)/2
2220 RE=RHO*MDE/QE
2230 PRINT "MEAN DIAMETER OF THE END RING=";MDE;"mt"
2240 PRINT "RESISTANCE OF THE END RING=";RE;"Ohms"
2250 CER=2*IE^2*RE
2260 TRCL=TCB+CER
2270 PRINT "TRCL=";TRCL;"Watts"
2280 REM******************************************************
2290 REM                     ROTOR CORE DESIGN
2300 REM******************************************************
2310 DCR=DCS
2320 IDRL=DR*10^(3)-2*DRS-2*DCR*10^(3)
2330 PRINT "INNER DIAMETER OF ROTOR LAMINATION=";IDRL;"mt"
2340 REM******************************************************
2350 REM                NO LOAD CURRENT CALCULATION
2360 REM::::::::::::::::::::::::::::::::::::::::::::::::::::::::
2370 REM                MAGNETISING CURRENT CALCULATIONS
2380 REM::::::::::::::::::::::::::::::::::::::::::::::::::::::::
2390 REM                  AIR GAP m.m.f.CALCULATIONS
2400 REM******************************************************
2410 WSO=3
2420 CGCS=1/(1+3.5*LG*10^(-3)/(WSO*.001))
2430 YSS1=YSS-CGCS*WSS
2440 AMEW=4*3.14*10^(-7)
2450 RGSI=LG*10^(-3)/(AMEW*YSS1*L)
2460 GCFS=YSS/(YSS-CGCS*WSO*10^(-3))
2470 CGCR=1/(1+3.5*LG*10^(-3)/(WRS*.001))
2480 GCFR=YSR/(YSR-CGCR*WRS*.001)
2490 CGCD=1/(1+3.5*LG*10^(-3)/(2*WO))
2500 IF LB=.1 GOTO 2530
```

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```
2510 GCFD=L/(L+CSCD*1*WD)
2520 GOTO 2540
2530 GCFD=L/(L+CSCD*2*WD)
2540 GCFT=GCFS*GCFR*GCFD
2550 EAGL=LG*10^(-3)*GCFT
2560 ATG=800000!*1.36*BAV*EAGL
2570 PRINT "AIR GAP m.m.f=";ATG;"A"
2580 REM******************************************************************
2590 REM                    CALCULATION OF STATOR TEETH mmf
2600 REM******************************************************************
2610 WTS=(3.14*(D+2*DPS/3))/SS-WSS
2620 ASI=SS/P*LI*WTS
2630 BTSS=FLUX/ASI
2640 BTSS1=1.36*BTSS
2650 FD11=BTSS1
2660 GOSUB 6510
2670 SATSI=AIFM1
2680 ATSI=SATSI*DSS
2690 PRINT "TOTAL mmf FOR STATOR TEETH=";ATSI;"A"
2700 REM******************************************************************
2710 REM               STATOR CORE mmf CALCULATION
2720 REM******************************************************************
2730 AUSC=DCS*LI
2740 BCS=FI/AUSC
2750 FD11=BCS
2760 GOSUB 6530
2770 SATSC=AIFM1
2780 PRINT "mmf PER METER FOR STATOR AND ROTOR CORE=";SATSC;"A"
2790 SCPATH=(3.14*(D+2*DSS+DCS))/(3*P)
2800 ATSC=SATSC*SCPATH
2810 PRINT "TOTAL mmf FOR STATOR CORE=";ATSC;"A"
2820 REM******************************************************************
2830 REM               ROTOR TEETH mmf CALCULATION
2840 REM******************************************************************
2850 WRT=(3.14*(DR*10^3-4/3*DRS))/SR-WRS
2860 ARI=(SR/P)*LI*WRT*10^(-3)
2870 BTRS=FLUX/ARI
2880 BTRS1=1.36*BTRS
2890 FD11=BTRS1
2900 GOSUB 6710
2910 SATRI=AIFM1
2920 ATRT=SATRI*DRS*10^(-3)
2930 PRINT "TOTAL mmf FOR ROTOR TEETH=";ATRT;"A"
2940 REM******************************************************************
2950 REM               ROTOR CORE mmf CALCULATION
2960 REM******************************************************************
2970 RCPATH=(3.14*(D-2*DRS*10^(-3)-DCS))/(3*P)
2980 ATRC=SATSC*RCPATH
2990 PRINT "TOTAL mmf FOR ROTOR TEETH=";ATRC;"A"
3000 TAT=ATG+ATSI+ATSC+ATRT+ATRC
```

```
3010 PRINT "TOTAL mmf REQUIRED=";TAT;"A"
3020 CIM=.427*P*TAT/(KW*TS1)
3030 PRINT "MAGNETISING CURRENT PER PHASE=";CIM;"Amps"
3040 REM *************************************************************
3050 REM              CALCULATION OF LOSS COMPONENT
3060 REM *************************************************************
3070 LWT=3.14*(D+DSS)/SS-WSS
3080 DENI=7600
3090 WIST=DENI*WSS*LWT*LI*DSS
3100 FRDIM=3.14/2*WSS
3110 FLD11=FRDIM
3120 GOSUB 6910
3130 SPLST=CORLOSS
3140 PRINT "SPECIFIC IRON LOSS=";SPLST;"W/Kg"
3150 TLIST=SPLST*WIST
3160 PRINT "TOTAL IRON LOSS IN STATOR TEETH=";TLIST;"Watts"
3170 REM *************************************************************
3180 REM              IRON LOSS CALCULATION IN STATOR CORE
3190 REM *************************************************************
3200 FPSC=3.14*(DO-DCS)
3210 WTCI=DENI*FPSC*DCS*LI
3220 BCS=FLUX/(2*LI*DCS)
3230 FLDT1=BCS
3240 GOSUB 7090
3250 SPLC=CORLOSS
3260 PRINT "SPECIFIC IRON LOSS IN STATOR CORE=";SPLC;"W/Kg"
3270 LIC=SPLC*WTCI
3280 PRINT "TOTAL IRON LOSS IN STATOR CORE=";LIC;"Watts"
3290 TIL=2*(TLIST+LIC)
3300 PRINT "TOTAL IRON LOSS=";TIL"Watts"
3310 FWL=.01*R*10^(+3)
3320 PRINT "FRICTION AND WINDAGE LOSS=";FWL"Watts"
3330 NLL=TIL+FWL
3340 PRINT "NO-LOAD LOSSES=";NLL"Watts"
3350 CIL=NLL/(3*V)
3360 PRINT "LOSS COMPONENT OF NO-LOAD CURRENT PER PHASE=";CIL;"Amperes"
3370 CINL=SQR(CIM^2+CIL^2)
3380 PRINT "NO-LOAD CURRENT PER PHASE=";CINL;"Amperes"
3390 PFNL=CIL/CINL
3400 PRINT "NO-LOAD POWER FACTOR=";PFNL
3410 XM=V/CIM
3420 PRINT "MAGNETISING REACTANCE=";XM;"Ohms"
3430 FM=V/CIL
3440 PRINT "RESISTANCE DUE TO CORE LOSSES=";FM;"Ohms"
3450 REM *************************************************************
3460 REM              CALCULATION OF COPPER LOSSES
3470 REM *************************************************************
3480 SCLP=LMT*TS1
3490 RS=.021*SCLP/ASC1
3500 SCLOS=3*RS*IS^2
```

```
3510 TCLOS=SCLOS+TRCL
3520 PRINT "TOTAL COPPER LOSS=";TCLOS;"Watts"
3530 TL=TCLOS+NLL
3540 INNPUT=R+TL*10^(-3)
3550 E=R*1000/(R*1000+TCLOS+NLL)
3560 PEREFF=E*100
3570 PRINT "EFFICIENCY OF THE MOTOR=";PEREFF;"%"
3580 SLIP=TRCL/(R*1000+TRCL+FWL)
3590 PRINT "SLIP=";SLIP
3600 REM********************************************************
3610 REM            CALCULATION OF STATOR TEMPERATURE RISE
3620 REM********************************************************
3630 SSO=3.14*DO*L
3640 PRINT "SSO=";SSO
3650 CCOS=.033
3660 LDFOS=SSO/CCOS
3670 ICYS=3.14*D*L
3680 PERISPD=3.14*D*NS
3690 CCOFIS=CCOS/(1+.1*PERISPD)
3700 LDFISS=ICYS/CCOFIS
3710 IF L>.1 GOTO 3740
3720 SSD=3.14*(DO^2-D^2)*3/4
3730 GOTO 3750
3740 SSD=3.14*(DO^2-D^2)
3750 SCD=.15/(.1*PERISPD)
3760 LDESD=SSD/SCD
3770 TLDS=LDFOS+LDFISS+LDESD
3780 PRINT "TLDS=";TLDS
3790 SLOS=SCLOS*2*L/LMT+TIL
3800 PRINT "SLOS=";SLOS
3810 STRIS=SLOS/TLDS
3820 PRINT "STATOR TEMPERATURE RISE=";STRIS;"Degrees"
3830 REM********************************************************
3840 REM            ROTOR TEMPERATURE RISE
3850 REM********************************************************
3860 OCYSR=3.14*DR*LI
3870 CCORS=.033/(1+.1*PERISPD)
3880 IF L>.1 THEN 3910
3890 SVD=3.14*(DR^2-IDRL^2)*3/4
3900 GOTO 3920
3910 SVD=3.14*(DR^2-(IDRL*10^(-3))^2)
3920 CCFVD=.15/(.1*PERISPD)
3930 RTRISE=(TRCL+FWL)/(OCYSR/CCORS+SVD/CCFVD)
3940 PRINT "ROTOR TEMPERATURE RISE=";RTRISE;"Degrees"
3950 REM********************************************************
3960 REM            CALCULATION OF COST
3970 REM********************************************************
3980 DENIR=7.85
3990 WETST=DENIR*SS*LI*DOS*MWCT
4000 PRINT "WETST=";WETST
```

```
4010 WETCI=DENIR*3.14*(DC-DCS)*DCS*LI
4020 PRINT "WETCI=";WETCI
4030 WETRI=DENIR*LI*(3.14/4*(DR^2-(IDRL*10^(-3))^2)-(CR*0RS*.001*WRS*.001))
4040 PRINT "WETRI=";WETRI
4050 INPUT "SPECIFIC COST OF IRON=";SPCIR
4060 TOTIC=SPCIR*(WETST+WETCI+WETRI)
4070 PRINT "TOTIC=";TOTIC
4080 DENCO=8.93
4090 WETSW=TS1*ASC1*DENCO*10^(-6)
4100 PRINT "WETSW=";WETSW
4110 WETRW=(SR*AB*LB)+(2*3.14*QE*WDE*.001*DENCO*10^(-6))
4120 PRINT "WETRW=";WETRW
4130 INPUT "SPECIFIC COST OF STATOR COPPER=";SPCOWM
4140 INPUT "SPECIFIC COST OF ROTOR COPPER=";SPORCW
4150 TCOW=SPCOWM*WETSW+SPORCW*WETRW
4160 PRINT "TCOW=";TCOW
4170 TOTC=TOTIC+TCOW
4180 PRINT "TOTC=";TOTC
4190 PRINT "TOTAL COST OF THE ACTIVE MATERIAL=";TOTC
4200 LPRINT "                    DESIGN SHEET"
4210 LPRINT "                    ~~~~~~ ~~~~~"
4220 LPRINT "KW-";R;"                  PHASE-";PH;"              FREQUENCY-";F;"HZ"
4230 LPRINT
4240 LPRINT "VOLTAGE-";V;"Volts";"  CONNECTION-DELTA";"       TYPE-CAGE"
4250 LPRINT
4260 LPRINT "                         RATING"
4270 LPRINT "                         ~~~~~~"
4280 LPRINT
4290 LPRINT "RATING OF THE MACHINE                    =";R;"Kw"
4300 LPRINT
4310 LPRINT "SUPPLY VOLTAGE                           =";V;"Volts"
4320 LPRINT
4330 LPRINT "SUPPLY FREQUENCY                         =";F;"Hz"
4340 LPRINT
4350 LPRINT "NUMBER OF PHASES                         =";PH
4360 LPRINT
4370 LPRINT "EFFICIENCY OF THE MOTOR                  =";E
4380 LPRINT
4390 LPRINT "POWER FACTOR                             =";C
4400 LPRINT
4410 LPRINT "NUMBER OF POLES                          =";P
4420 LPRINT
4430 LPRINT "SPEED OF THE ROTOR                       =";N;"rpm"
4440 LPRINT
4450 LPRINT "KVA INPUT                                =";Q;"KVA"
4460 LPRINT
4470 LPRINT "STATOR WINDING FACTOR                    =";KW
4480 LPRINT
4490 LPRINT
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```
4500 LPRINT "
4510 LPRINT "                              LOADING"
4520 LPRINT
4530 LPRINT "SPECIFIC MAGNETIC LOADING
4540 LPRINT                                                    ="¡BAV¡"WB/3¡"
4550 LPRINT "SPECIFIC ELECTRIC LOADING
4560 LPRINT                                                    ="¡AC¡"A/M¡"
4570 LPRINT "OUTPUT COEFFICIENT
4580 LPRINT                                                    ="¡CO
4590 LPRINT "D^2*L
4600 LPRINT
4610 LPRINT                                                    ="¡¡SL¡"Cubic M"
4620 LPRINT "
4630 LPRINT "                          MAIN DIMENSIONS"
4640 LPRINT
4650 LPRINT "DIAMETER OF THE CORE
4660 LPRINT
4670 LPRINT "LENGTH OF THE CORE                               ="¡D¡"Mtrs"
4680 LPRINT
4690 LPRINT "NET IRON LENGTH                                  ="¡L¡"Mtrs"
4700 LPRINT
4710 LPRINT "POLE PITCH                                       ="¡LI¡"Mtrs"
4720 LPRINT
4730 LPRINT                                                   ="¡TP¡"Mtrs"
4740 LPRINT "
4750 LPRINT "                             STATOR"
4760 LPRINT
4770 LPRINT "TYPE OF WINDING
4780 LPRINT
4790 LPRINT "CONNECTION                                       ="SINGLE LAYER"
4800 LPRINT
4810 LPRINT "PHASE VOLTAGE                                    ="DELTA"
4820 LPRINT
4830 LPRINT "FLUX PER POLE                                    ="¡V¡"Volts"
4840 LPRINT
4850 LPRINT "TURNS PER PHASE                                  ="¡FLUX¡"Wb"
4860 LPRINT
4870 LPRINT "NUMBER OF STATOR SLOTS                           ="¡T
4880 LPRINT
4890 LPRINT "SLOTS PER  POLE PER PHASE                        ="¡SS
4900 LPRINT
4910 LPRINT "COIL SPAN                                        ="¡SPP
4920 LPRINT
4930 LPRINT "DISTRIBUTION FACTOR                              ="¡CS¡"Slots"
4940 LPRINT
4950 LPRINT "PITCH FACTOR                                     ="¡KD
4960 LPRINT
4970 LPRINT "WINDING FACTOR                                   ="¡KP
4980 LPRINT
4990 LPRINT "SLOT PITCH                                       ="¡KWS
5000 LPRINT                                                   ="¡YCS¡"Mtrs"
```

```
5010 LPRINT "CONDUCTORS PER SLOT                        =";ZS
5020 LPRINT
5030 LPRINT "BARE CONDUCTOR DIAMETER                    =";CD1;"Mtre"
5040 LPRINT
5050 LPRINT "CONDUCTOR OVERALL DIAMETER                 =";OD1;"Mtre"
5060 LPRINT
5070 LPRINT "AREA OF THE CONDUCTOR                       =";AS1;"Sq.mm"
5080 LPRINT
5090 LPRINT "CURRENT DENSITY                            =";JD;"A/Sq.mm"
5100 LPRINT
5110 LPRINT "LENGTH OF MEAN TURN                         =";LMT;"Mtr"
5120 LPRINT
5130 LPRINT "STATOR RESISTANCE PER PHASE                =";RD;"Ohms"
5140 LPRINT
5150 LPRINT "STATOR COPPER LOSS                         =";SCLOS;"Watts"
5160 LPRINT
5170 LPRINT "DEPTH OF THE STATOR CORE                   =";DCS;"Mtr"
5180 LPRINT
5190 LPRINT "OUTER DIAMETER OF STATOR LAMINATIONS       =";DO;"Mtr"
5200 LPRINT
5210 LPRINT
5220 LPRINT "
5230 LPRINT "                              ROTOR"
5240 LPRINT
5250 LPRINT "LENGTH OF AIR GAP                          =";LG;"mm"
5260 LPRINT
5270 LPRINT "DIAMETER OF ROTOR                          =";DR;"Mtr"
5280 LPRINT
5290 LPRINT "TYPE OF WINDING                            =SQUIRREL CAGE"
5300 LPRINT
5310 LPRINT "NUMBER OF SLOTS                            =";SR
5320 LPRINT
5330 LPRINT "SLOTS PER POLE PER PHASE                   =";SPP
5340 LPRINT
5350 LPRINT "WINDING FACTOR                             =";KWS
5360 LPRINT
5370 LPRINT "SLOT PITCH                                 =";YSR;"Mtr"
5380 LPRINT
5390 LPRINT "BAR CURRENT                                =";IB;"Amps"
5400 LPRINT
5410 LPRINT "AREA OF THE BAR                            =";AB;"Sq.mm"
5420 LPRINT
5430 LPRINT "LENGTH OF THE BAR                          =";LB;"Mtre"
5440 LPRINT
5450 LPRINT "CURRENT DENSITY                            =";RCD;"A/Sq.mm"
5460 LPRINT
5470 LPRINT "RESISTANCE OF EACH BAR                     =";RB;"Ohms"
5480 LPRINT
5490 LPRINT "END RING CURRENT                           =";IE;"Ohms"
5500 LPRINT
```

```
5510 LPRINT "AREA OF THE END RING                          =";AE;"Sq.mm"
5520 LPRINT
5530 LPRINT "MEAN DIAMETER  OF THE END RING                =";MDE;"mm"
5540 LPRINT
5550 LPRINT "RESISTANCE OF EACH RING                       =";RE;"Ohms"
5560 LPRINT
5570 LPRINT "TOATL ROTOR COPPER LOSS                       =";TRCL;"Watts"
5580 LPRINT
5590 LPRINT "DEPTH OF THE ROTOR CORE                       =";DCR;"mm"
5600 LPRINT
5610 LPRINT
5620 LPRINT "
5630 LPRINT "                         LOSSES"
5640 LPRINT
5650 LPRINT "TOTAL mmf REQUIRED                            =";TAT;"A"
5660 LPRINT
5670 LPRINT "MAGNETISING CURRENT PER PHASE                 =";CIM;"Amps"
5680 LPRINT
5690 LPRINT "MAGNETISING REACTANCE                         =";XM;"Ohms"
5700 LPRINT
5710 LPRINT "CORE LOSS                                     =";CORLOSS;"Watts"
5720 LPRINT
5730 LPRINT "TOTAL IRON LOSSES                             =";TIL;"Watts"
5740 LPRINT
5750 LPRINT "FRICTION AND WINDAGE LOSSES                   =";FWL;"Watts"
5760 LPRINT
5770 LPRINT "NO LOAD LOSSES                                =";NLL;"Watts"
5780 LPRINT
5790 LPRINT "TOTAL COPPER LOSSES                           =";TCLOS;"Watts"
5800 LPRINT
5810 LPRINT "LOSS COMPONENT                                =";CIL;"Amps"
5820 LPRINT
5830 LPRINT "NO LOAD CURRENT PER PHASE                     =";CINL;"Amps"
5840 LPRINT
5850 LPRINT "NO LOAD POWER FACTOR                          =";PFNL
5860 LPRINT
5870 LPRINT "STATOR TEMPERATURE RISE                       =";STRIE;"Degrees"
5880 LPRINT
5890 LPRINT "ROTOR TEMPERATURE RISE                        =";RTRISE;"Degrees"
5900 LPRINT
5910 LPRINT
5920 LPRINT "
5930 LPRINT "              WEIGHT OF THE MATERIALS USED"
5940 LPRINT
5950 LPRINT "WEIGHT OF THE IRON IN STATOR TEETH            =";WSTST;"Kg"
5960 LPRINT
5970 LPRINT "WEIGHT OF THE IRON IN STATOR CORE             =";WSTCT;"Kg"
5980 LPRINT
5990 LPRINT "WEIGHT OF THE IRON IN ROTOR                   =";WSTRT;"Kg"
6000 LPRINT
```

```basic
6010 LPRINT "WEIGHT OF THE STATOR WINDINGS                    =";WETSW;"Kg"
6020 LPRINT
6030 LPRINT "WEIGHT OF THE ROTOR WINDINGS                     =";WETRW;"Kg"
6040 LPRINT
6050 LPRINT
6060 LPRINT "                    COST OF THE MATERIALS USED"
6070 LPRINT "                    ~~~~ ~~ ~~~ ~~~~~~~~~ ~~~~"
6080 LPRINT
6090 LPRINT "SPECIFIC COST OF IRON PER Kg.                    =";"Rs.";SPCIR
6100 LPRINT
6110 LPRINT "SPECIFIC COST OF STATOR COPPER PER Kg.           =";"Rs.";SPCCUS
6120 LPRINT
6130 LPRINT "SPECIFIC COST OF ROTOR COPPER PER Kg.            =";"Rs.";SPCRCU
6140 LPRINT
6150 LPRINT "TOTAL COST OF ACTIVE MATERIALS                   =";"Rs.";TCTC
6160 LPRINT
6170 LPRINT
6180 LPRINT "                         PERFORMANCES"
6190 LPRINT "                         ~~~~~~~~~~~~"
6200 LPRINT
6210 LPRINT "TOTAL LOSSES                                     =";TL;"WATTS"
6220 LPRINT
6230 LPRINT "OUTPUT                                           =";P;"KW"
6240 LPRINT
6250 LPRINT "INPUT                                            =";INPUT;"KW"
6260 LPRINT
6270 LPRINT "EFFICIENCY                                       =";PEREFF;"%"
6280 LPRINT
6290 LPRINT "SLIP                                             =";SLIP
6300 END
6310 REM**************************************************************
6320 REM          SUB ROUTINE TO CALCULATE mmf PER METER
6330 REM**************************************************************
6340 FOR J=1 TO 31
6350 READ FD1(J),ATPM(J)
6360 NEXT J
6370 DATA .5,200,.6,210,.7,220,.8,300,.9,330
6380 DATA .95,350,1,400,1.05,410,1.1,420,1.15,450
6390 DATA 1.2,500,1.25,600,1.3,700,1.35,900,1.4,1100
6400 DATA 1.45,1450,1.5,1700,1.55,2400,1.6,2900,1.65,4000
6410 DATA 1.7,5000,1.75,7000,1.8,9000,1.85,12000,1.9,14000
6420 DATA 1.95,19000,2,26000,2.05,34000,2.1,42500,2.15,5500
6430 DATA 2.2,70000
6440 FOR J=1 TO 31
6450 IF FD11=FD1(J) THEN 6500
6460 IF FD11<FD1(J) THEN 6480
6470 NEXT J
6480 ATPM1=ATPM(J)-(ATPM(J)-ATPM(J-1))/(FD1(J)-FD1(J-1))*(FD1(J)-FD11)
6490 GOTO 6510
6500 ATPM1=ATPM(J)
```

```
6510 PRINT "AMPERE TURNS FOR YOKE=";ATSY1
6520 RETURN
6530 REM ********************************************************
6535 REM           SUB-ROUTINE TO CALCULATE STATOR CORE mmf
6540 REM ********************************************************
6550 FOR K=1 TO 31
6560 READ FD1(K),ATPM(K)
6570 NEXT K
6580 DATA .5,200,.6,210,.7,220,.8,300,.9,330,.95,350
6590 DATA 1,400,1.05,410,1.1,420,1.15,460,1.2,500,1.25,600,1.3,700
6600 DATA 1.35,900,1.4,1100,1.45,1450,1.5,1700,1.55,2600,1.6,2700
6610 DATA 1.65,4000,1.7,5000,1.75,7000,1.8,9000,1.85,1600,1.9,14000
6620 DATA 1.95,17000,2,26000,2.05,34000,2.1,42500,2.15,55000,2.2,70000
6630 FOR I=1 TO 31
6640 IF FD11=FD1(K) THEN 6680
6650 IF FD11<FD1(K) THEN 6670
6660 NEXT K
6670 ATPM1=ATPM(K)-(ATPM(K)-ATPM(K-1))/(FD1(K)-FD1(K-1))*(FD1(K)-FD11)
6680 ATPM1=ATPM(K)
6690 PRINT "AMPERE TURNS PER METER FOR STATOR CORE=";ATPM1
6700 RETURN
6710 REM ********************************************************
6720 REM           SUB ROUTINE TO CALCULATE ROTOR TEETH mmf
6730 REM ********************************************************
6740 FOR G=1 TO 31
6750 READ FD1(G),ATPM(G)
6760 NEXT G
6770 DATA .5,200,.6,210,.7,220,.8,300,.9,330,.95,350
6780 DATA 1,400,1.05,410,1.1,420,1.15,460,1.2,500,1.25,600,1.3,700
6790 DATA 1.35,900,1.4,1100,1.45,1450,1.5,1700,1.55,2600,1.6,2700
6800 DATA 1.65,4000,1.7,5000,1.75,7000,1.8,9000,1.85,12000,1.9,14000
6810 DATA 1.95,17000,2,26000,2.05,34000,2.1,42500,2.15,55000,2.2,70000
6820 FOR G=1 TO 31
6830 IF FD11=FD1(G) THEN 6890
6840 IF FD11<FD1(G) THEN 6870
6850 PRINT "FD1(G-1)=";FD1(G-1)
6860 NEXT G
6870 ATPM1=ATPM(G)-(ATPM(G)-ATPM(G-1))/(FD1(G)-FD1(G-1))*(FD1(G)-FD11)
6880 GO TO 6900
6890 ATPM1=ATPM(G)
6900 PRINT"AMPERE TURNS PER METER ROTOR TEETH=";ATPM1
6910 RETURN
6920 REM ********************************************************
6930 REM           SUB ROUTINE TO CALCULATE  SPECIFIC IRON LOSS  IRON CORE
6940 REM ********************************************************
6950 FOR K=1 TO 15
6960 READ FLDT(K),CORLOS(K)
6970 NEXT K
6980 DATA .4,.8,.5,1.2,.6,1.6,.7,2,.8,2.5,.9,3,1,3.4,1.1,4.1,1.2,5,1.3,5.9
6990 DATA 1.4,7,1.5,8.1,1.6,9.5,1.7,10.7,1.8,11.7
7000 FOR K=1 TO 15
```

```basic
7010 IF FLDT1=FLDT(K) THEN 7060
7020 IF FLDT1<FLDT(K) THEN 7040
7030 NEXT K
7040 CORLOSS=CORLOS(K) - (CORLOS(K) -CORLOS(K-1))/(FLDT(K) -FLDT(K-1)) * (FLDT(K) -FLDT1)
7050 GOTO 7070
7060 CORLOSS=CORLOS(K)
7070 PRINT "SPECIFIC IRON LOSS IN STATOR CORE=";CORLOSS;"W/Kg"
7080 RETURN
7090 REM**********************************************************************
7100 REM          SUB ROUTINE TO CALCULATE SPECIFIC IRON LOSS (GRAPH)
7110 REM **********************************************************************
7120 FOR H=1 TO 15
7130 READ FLDT(H),CORLOS(H)
7140 NEXT H
7150 DATA .4,.8,.5,1.0,.6,1.6,.7,2,.8,2.5,.9,3,1,3.6,1.1,4.1,1.2,5,1.3,5.7
7160 DATA 1.4,7,1.5,8.1,1.6,9.5,1.7,10.7,1.8,11.7
7170 FOR H= 1 TO 15
7180 IF FLDT1<FLDT(H) THEN 7200
7190 NEXT H
7200 CORLOSS=CORLOS(H) - (CORLOS(H) -CORLOS(H-1))/(FLDT(H) -FLDT(H-1)) * (FLDT(H) -FLDT1)
7210 RETURN
```

DESIGN SHEET

KW- 2.2	PHASE- 3	FREQUENCY 50 Hz
VOLTAGE- 400 Volts	CONNECTION-DELTA	TYPE-CAGE

RATING

RATING OF THE MACHINE	= 2.2 Kw
SUPPLY VOLTAGE	= 400 Volts
SUPPLY FREQUENCY	= 50 Hz
NUMBER OF PHASES	= 3
EFFICIENCY OF THE MOTOR	= .8114268
POWER FACTOR	= .825
NUMBER OF POLES	= 4
SPEED OF THE MOTOR	= 1500 Rpm
KVA INPUT	= 3.333334 KVA
STATOR WINDING FACTOR	= .955

LOADING

SPECIFIC MAGNETIC LOADING	= .5 Wb/Sq.Mtr
SPECIFIC ELECTRIC LOADING	= 21000 A/Mtr
OUTPUT COEFFICIENT	= 110.3025
D^2*L	= 1.208797E-03 Cubic Mtr

MAIN DIMENSIONS

DIAMETER OF THE CORE	= 9.873125E-02 Mtrs
LENGTH OF THE CORE	= .1240065 Mtrs
NET IRON LENGTH	= 9.360581E-02 Mtrs
POLE PITCH	= 7.750403E-02 Mtrs

STATOR

TYPE OF WINDING	=SINGLE LAYER MUSH
CONNECTION	=DELTA
PHASE VOLTAGE	= 400 Volts
FLUX PER POLE	= .0048055 Wb
TURNS PER PHASE	= 392
NUMBER OF STATOR SLOTS	= 24
SLOTS PER POLE PER PHASE	= 2
COIL SPAN	= 6 Slots
DISTRIBUTION FACTOR	= .9659601
PITCH FACTOR	= 1
WINDING FACTOR	= .9659601
SLOT PITCH	= 1.291734E-02 Mtrs
CONDUCTORS PER SLOT	= 98
BARE CONDUCTOR DIAMETER	= .9405544 mm
CONDUCTOR OVERALL DIAMETER	= 1.031554 mm
AREA OF THE CONDUCTOR	= .6944446 Sq.mm
CURRENT DENSITY	= 4 A/Sq.mm
LENGTH OF MEAN TURN	= .6662722 Mtr
STATOR RESISTANCE PER PHASE	= 7.898042 Ohms
STATOR COPPER LOSS	= 182.8251 Watts
DEPTH OF THE STATOR CORE	= 1.833487E-02 Mtr
OUTER DIAMETER OF STATOR LAMINATIONS	= .2404933 Mtr

ROTOR

LENGTH OF AIR GAP	= .421299 mm
DIAMETER OF ROTOR	= 9.788865E-02 Mtr

TYPE OF WINDING   =SQUIRREL CAGE

NUMBER OF SLOTS   = 26

SLOTS PER POLE PER PHASE   = 2

WINDING FACTOR   = .9659601

SLOT PITCH   = 1.182194E-02 Mtr

BAR CURRENT   = 133.5006 Amps

AREA OF THE BAR   = 26 Sq.mm

LENGTH OF THE BAR   = .1650065 Mtrs

CURRENT DENSITY   = 5 A/Sq.mm

RESISTANCE OF EACH BAR   = 1.225621E-04 Ohms

END RING CURRENT   = 276.3548 Amps

AREA OF THE END RING   = 55 Sq.mm

MEAN DIAMETER OF THE END RING   = 6.608865E-02 mm

RESISTANCE OF EACH RING   = 2.523385E-05 Ohms

TOATL ROTOR COPPER LOSS   = 60.64749 Watts

DEPTH OF THE ROTOR CORE   = 1.833487E-02 Mtr

                        LOSSES
                        ~~~~~~

TOTAL mmf REQUIRED   = 381.7979 A

MAGNETISING CURRENT PER PHASE   = 1.741935 Amps

MAGNETISING REACTANCE   = 229.6297 Ohms

CORE LOSS   = 7 Watts

TOTAL IRON LOSSES   = 245.801 Watts

FRICTION AND WINDAGE LOSSES   = 22 Watts

NO LOAD LOSSES   = 267.801 Watts

TOTAL COPPER LOSSES   = 243.4725 Watts

LOSS COMPONENT   = .2231675 Amps

NO LOAD CURRENT PER PHASE   = 1.756173 Amps

NO LOAD POWER FACTOR   = .1270761

STATOR TEMPERATURE RISE   = 55.20039 Degrees

ROTOR TEMPERATURE RISE   = 49.09902 Degrees

WEIGHT OF THE MATERIALS USED

WEIGHT OF THE IRON IN STATOR TEETH   = 4.664019E-03 Kg

WEIGHT OF THE IRON IN STATOR CORE   = 9.393157E-03 Kg

WEIGHT OF THE IRON IN ROTOR   = 4.283738E-03 Kg

WEIGHT OF THE STATOR WINDINGS   = 2.430945E-03 Kg

WEIGHT OF THE ROTOR WINDINGS   = 121.2938 Kg

COST OF THE MATERIALS USED

SPECIFIC COST OF IRON PER Kg.   =Rs. 40

SPECIFIC COST OF STATOR COPPER PER Kg.   =Rs. 110

SPECIFIC COST OF ROTOR COPPER PER Kg.   =Rs. 15

TOTAL COST OF ACTIVE MATERIALS   =Rs. 1820.408

PERFORMANCES

TOTAL LOSSES   = 511.2736 Watts

OUTPUT   = 2.2 KW

INPUT   = 2.711274 KW

EFFICIENCY   = 81.14268 %

SLIP   = 2.656892E-02

DESIGN SHEET

KW- 7.5   PHASE- 3   FREQUENCY 50 Hz

VOLTAGE- 220 Volts   CONNECTION-DELTA   TYPE-CAGE

RATING

RATING OF THE MACHINE	= 7.5 Kw
SUPPLY VOLTAGE	= 220 Volts
SUPPLY FREQUENCY	= 50 Hz
NUMBER OF PHASES	= 3
EFFICIENCY OF THE MOTOR	= .8596937
POWER FACTOR	= .86
NUMBER OF POLES	= 4
SPEED OF THE MOTOR	= 1500 Rpm
KVA INPUT	= 10.25992 KVA
STATOR WINDING FACTOR	= .955

LOADING

SPECIFIC MAGNETIC LOADING	= .45 Wb/Sq.Mtr
SPECIFIC ELECTRIC LOADING	= 22000 A/Mtr
OUTPUT COEFFICIENT	= 103.9995
D^2*L	= 3.946142E-03 Cubic Mtr

MAIN DIMENSIONS

DIAMETER OF THE CORE	= .1464629 Mtrs
LENGTH OF THE CORE	= .1839574 Mtrs
NET IRON LENGTH	= .1475617 Mtrs
POLE PITCH	= .1149734 Mtrs

STATOR

TYPE OF WINDING	=SINGLE LAYER MUSH
CONNECTION	=DELTA
PHASE VOLTAGE	= 220 Volts
FLUX PER POLE	= 9.517592E-03 Wb
TURNS PER PHASE	= 109
NUMBER OF STATOR SLOTS	= 24
SLOTS PER POLE PER PHASE	= 2
COIL SPAN	= 6 Slots
DISTRIBUTION FACTOR	= .9659601
PITCH FACTOR	= 1
WINDING FACTOR	= .9659601
SLOT PITCH	= 1.916223E-02 Mtrs
CONDUCTORS PER SLOT	= 27
BARE CONDUCTOR DIAMETER	= 1.112513 mm
CONDUCTOR OVERALL DIAMETER	= 1.207513 mm
AREA OF THE CONDUCTOR	= 1.943166 Sq.mm
CURRENT DENSITY	= 4 A/Sq.mm
LENGTH OF MEAN TURN	= .8723536 Mtr
STATOR RESISTANCE PER PHASE	= 1.018183 Ohms
STATOR COPPER LOSS	= 738.1538 Watts
DEPTH OF THE STATOR CORE	= 2.303539E-02 Mtr
OUTER DIAMETER OF STATOR LAMINATIONS	= .2182689 Mtr

ROTOR

LENGTH OF AIR GAP	= .5282861 mm
DIAMETER OF ROTOR	= .1454063 Mtr

TYPE OF WINDING	=SQUIRREL CAGE
NUMBER OF SLOTS	= 26
SLOTS PER POLE PER PHASE	= 2
WINDING FACTOR	= .9659601
SLOT PITCH	= 1.756061E-02 Mtr
BAR CURRENT	= 216.5563 Amps
AREA OF THE BAR	= 43 Sq.mm
LENGTH OF THE BAR	= .2249574 Mtrs
CURRENT DENSITY	= 5 A/Sq.mm
RESISTANCE OF EACH BAR	= 9.520088E-05 Ohms
END RING CURRENT	= 448.2853 Amps
AREA OF THE END RING	= 89 Sq.mm
MEAN DIAMETER OF THE END RING	= 5.020633E-02 mm
RESISTANCE OF EACH RING	= 1.184644E-05 Ohms
TOATL ROTOR COPPER LOSS	= 120.8409 Watts
DEPTH OF THE ROTOR CORE	= 2.303539E-02 Mtr

LOSSES

TOTAL mmf REQUIRED	= 399.6943 A
MAGNETISING CURRENT PER PHASE	= 6.618944 Amps
MAGNETISING REACTANCE	= 33.23793 Ohms
CORE LOSS	= 7 Watts
TOTAL IRON LOSSES	= 290.0426 Watts
FRICTION AND WINDAGE LOSSES	= 75 Watts
NO LOAD LOSSES	= 365.0426 Watts
TOTAL COPPER LOSSES	= 858.9946 Watts
LOSS COMPONENT	= .5530948 Amps
NO LOAD CURRENT PER PHASE	= 6.642013 Amps

NO LOAD POWER FACTOR   = 8.327218E-02

STATOR TEMPERATURE RISE   = 60.36487 Degrees

ROTOR TEMPERATURE RISE   = 40.01905 Degrees

WEIGHT OF THE MATERIALS USED

WEIGHT OF THE IRON IN STATOR TEETH   = 2.26207E-03 Kg

WEIGHT OF THE IRON IN STATOR CORE   = 1.635772E-02 Kg

WEIGHT OF THE IRON IN ROTOR   = 1.757657E-02 Kg

WEIGHT OF THE STATOR WINDINGS   = 1.874067E-03 Kg

WEIGHT OF THE ROTOR WINDINGS   = 290.2367 Kg

COST OF THE MATERIALS USED

SPECIFIC COST OF IRON PER Kg.   =Rs. 40

SPECIFIC COST OF STATOR COPPER PER Kg.   =Rs. 110

SPECIFIC COST OF ROTOR COPPER PER Kg.   =Rs. 15

TOTAL COST OF ACTIVE MATERIALS   =Rs. 4355.204

PERFORMANCES

TOTAL LOSSES   = 1224.037 Watts

OUTPUT   = 7.5 KW

INPUT   = 8.724037 KW

EFFICIENCY   = 85.96937 %

SLIP   = .0157021

DESIGN SHEET

KW- 8.75   PHASE- 3   FREQUENCY 50 Hz

VOLTAGE- 415 Volts   CONNECTION-DELTA   TYPE-CAGE

RATING

RATING OF THE MACHINE	= 8.75 Kw
SUPPLY VOLTAGE	= 415 Volts
SUPPLY FREQUENCY	= 50 Hz
NUMBER OF PHASES	= 3
EFFICIENCY OF THE MOTOR	= .850255
POWER FACTOR	= .86
NUMBER OF POLES	= 6
SPEED OF THE MOTOR	= 1000 Rpm
KVA INPUT	= 11.9699 KVA
STATOR WINDING FACTOR	= .955

LOADING

SPECIFIC MAGNETIC LOADING	= .5 Wb/Sq.Mtr
SPECIFIC ELECTRIC LOADING	= 21000 A/Mtr
OUTPUT COEFFICIENT	= 110.3025
D^2*L	= 6.511133E-03 Cubic Mtr

MAIN DIMENSIONS

DIAMETER OF THE CORE	= .1981159 Mtrs
LENGTH OF THE CORE	= .1658891 Mtrs
NET IRON LENGTH	= .1313002 Mtrs
POLE PITCH	= .1036807 Mtrs

STATOR

TYPE OF WINDING	=SINGLE LAYER MUSH
CONNECTION	=DELTA
PHASE VOLTAGE	= 415 Volts
FLUX PER POLE	= 8.599746E-03 Wb
TURNS PER PHASE	= 227
NUMBER OF STATOR SLOTS	= 54
SLOTS PER POLE PER PHASE	= 3
COIL SPAN	= 9 Slots
DISTRIBUTION FACTOR	= .9598355
PITCH FACTOR	= 1
WINDING FACTOR	= .9598355
SLOT PITCH	= 1.152008E-02 Mtrs
CONDUCTORS PER SLOT	= 25
BARE CONDUCTOR DIAMETER	= .8749149 mm
CONDUCTOR OVERALL DIAMETER	= .9619081 mm
AREA OF THE CONDUCTOR	= 1.201798 Sq.mm
CURRENT DENSITY	= 4 A/Sq.mm
LENGTH OF MEAN TURN	= .8102438 Mtr
STATOR RESISTANCE PER PHASE	= 3.185563 Ohms
STATOR COPPER LOSS	= 883.3851 Watts
DEPTH OF THE STATOR CORE	= 2.339173E-02 Mtr
OUTER DIAMETER OF STATOR LAMINATIONS	= .2681376 Mtr

ROTOR

LENGTH OF AIR GAP	= .5625756 mm

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DIAMETER OF ROTOR	= .1969908 Mtr
TYPE OF WINDING	=SQUIRREL CAGE
NUMBER OF SLOTS	= 57
SLOTS PER POLE PER PHASE	= 3
WINDING FACTOR	= .9598355
SLOT PITCH	= 1.085177E-02 Mtr
BAR CURRENT	= 189.6352 Amps
AREA OF THE BAR	= 37 Sq.mm
LENGTH OF THE BAR	= .2068891 Mtrs
CURRENT DENSITY	= 5 A/Sq.mm
RESISTANCE OF EACH BAR	= 1.016952E-04 Ohms
END RING CURRENT	= 573.737 Amps
AREA OF THE END RING	= 114 Sq.mm
MEAN DIAMETER OF THE END RING	= .1112908 mm
RESISTANCE OF EACH RING	= 2.050093E-05 Ohms
TOATL ROTOR COPPER LOSS	= 221.952 Watts
DEPTH OF THE ROTOR CORE	= 2.339173E-02 Mtr

LOSSES

TOTAL mmf REQUIRED	= 622.6642 A
MAGNETISING CURRENT PER PHASE	= 7.424156 Amps
MAGNETISING REACTANCE	= 55.89862 Ohms
CORE LOSS	= 7 Watts
TOTAL IRON LOSSES	= 348.1933 Watts
FRICTION AND WINDAGE LOSSES	= 87.5 Watts
NO LOAD LOSSES	= 435.6933 Watts
TOTAL COPPER LOSSES	= 1105.337 Watts
LOSS COMPONENT	= .3499544 Amps

```
NO LOAD CURRENT PER PHASE                       = 7.432399 Amps

NO LOAD POWER FACTOR                            = 4.708499E-02

STATOR TEMPERATURE RISE                         = 62.76665 Degrees

ROTOR TEMPERATURE RISE                          = 54.00628 Degrees


              WEIGHT OF THE MATERIALS USED
              ~~~~~~ ~~ ~~~ ~~~~~~~~~ ~~~~

WEIGHT OF THE IRON IN STATOR TEETH              = 2.768404E-03 Kg

WEIGHT OF THE IRON IN STATOR CORE               = 1.852858E-02 Kg

WEIGHT OF THE IRON IN ROTOR                     = 2.422564E-02 Kg

WEIGHT OF THE STATOR WINDINGS                   = 2.414712E-03 Kg

WEIGHT OF THE ROTOR WINDINGS                    = 503.8127 Kg


              COST OF THE MATERIALS USED
              ~~~~ ~~ ~~~ ~~~~~~~~~ ~~~~

SPECIFIC COST OF IRON PER Kg.                   =Rs. 40

SPECIFIC COST OF STATOR COPPER PER Kg.          =Rs. 110

SPECIFIC COST OF ROTOR COPPER PER Kg.           =Rs. 15

TOTAL COST OF ACTIVE MATERIALS                  =Rs. 7559.277


                    PERFORMANCES
                    ~~~~~~~~~~~~

TOTAL LOSSES                                    = 1541.03 Watts

OUTPUT                                          = 8.75 KW

INPUT                                           = 10.29103 KW

EFFICIENCY                                      = 85.0255 %

SLIP                                            = .0244995
```

DESIGN SHEET

KW- 11   PHASE- 3   FREQUENCY 50 Hz

VOLTAGE- 440 Volts   CONNECTION-DELTA   TYPE-CAGE

RATING

RATING OF THE MACHINE	= 11 Kw
SUPPLY VOLTAGE	= 440 Volts
SUPPLY FREQUENCY	= 50 Hz
NUMBER OF PHASES	= 3
EFFICIENCY OF THE MOTOR	= .8543464
POWER FACTOR	= .86
NUMBER OF POLES	= 6
SPEED OF THE MOTOR	= 1000 Rpm
KVA INPUT	= 14.8729 KVA
STATOR WINDING FACTOR	= .955

LOADING

SPECIFIC MAGNETIC LOADING	= .45 Wb/Sq.Mtr
SPECIFIC ELECTRIC LOADING	= 22000 A/Mtr
OUTPUT COEFFICIENT	= 103.9995
D^2*L	= 8.580564E-03 Cubic Mtr

MAIN DIMENSIONS

DIAMETER OF THE CORE	= .2172063 Mtrs
LENGTH OF THE CORE	= .1818741 Mtrs
NET IRON LENGTH	= .1456867 Mtrs
POLE PITCH	= .1136713 Mtrs

STATOR

TYPE OF WINDING	=SINGLE LAYER MUSH
CONNECTION	=DELTA
PHASE VOLTAGE	= 440 Volts
FLUX PER POLE	= 9.303239E-03 Wb
TURNS PER PHASE	= 223
NUMBER OF STATOR SLOTS	= 54
SLOTS PER POLE PER PHASE	= 3
COIL SPAN	= 9 Slots
DISTRIBUTION FACTOR	= .9598355
PITCH FACTOR	= 1
WINDING FACTOR	= .9598355
SLOT PITCH	= 1.263015E-02 Mtrs
CONDUCTORS PER SLOT	= 24
BARE CONDUCTOR DIAMETER	= .9471442 mm
CONDUCTOR OVERALL DIAMETER	= 1.038144 mm
AREA OF THE CONDUCTOR	= 1.408419 Sq.mm
CURRENT DENSITY	= 4 A/Sq.mm
LENGTH OF MEAN TURN	= .8651922 Mtr
STATOR RESISTANCE PER PHASE	= 2.786466 Ohms
STATOR COPPER LOSS	= 1061.253 Watts
DEPTH OF THE STATOR CORE	= 2.280638E-02 Mtr
OUTER DIAMETER OF STATOR LAMINATIONS	= .3000397 Mtr

ROTOR

LENGTH OF AIR GAP	= .5975133 mm
DIAMETER OF ROTOR	= .2160113 Mtr

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TYPE OF WINDING	=SQUIRREL CAGE
NUMBER OF SLOTS	= 57
SLOTS PER POLE PER PHASE	= 3
WINDING FACTOR	= .9598355
SLOT PITCH	= 1.189957E-02 Mtr
BAR CURRENT	= 218.3224 Amps
AREA OF THE BAR	= 43 Sq.mm
LENGTH OF THE BAR	= .2228741 Mtrs
CURRENT DENSITY	= 5 A/Sq.mm
RESISTANCE OF EACH BAR	= 9.431922E-05 Ohms
END RING CURRENT	= 660.5297 Amps
AREA OF THE END RING	= 132 Sq.mm
MEAN DIAMETER OF THE END RING	= .1165113 mm
RESISTANCE OF EACH RING	= 1.853588E-05 Ohms
TOATL ROTOR COPPER LOSS	= 272.4291 Watts
DEPTH OF THE ROTOR CORE	= 2.280638E-02 Mtr

LOSSES

TOTAL mmf REQUIRED	= 425.1449 A
MAGNETISING CURRENT PER PHASE	= 5.280304 Amps
MAGNETISING REACTANCE	= 83.32855 Ohms
CORE LOSS	= 7 Watts
TOTAL IRON LOSSES	= 431.6576 Watts
FRICTION AND WINDAGE LOSSES	= 110 Watts
NO LOAD LOSSES	= 541.6576 Watts
TOTAL COPPER LOSSES	= 1333.682 Watts
LOSS COMPONENT	= .4103467 Amps
NO LOAD CURRENT PER PHASE	= 5.296224 Amps

NO LOAD POWER FACTOR   = .0774791

STATOR TEMPERATURE RISE   = 61.63038 Degrees

ROTOR TEMPERATURE RISE   = 52.10051 Degrees

                WEIGHT OF THE MATERIALS USED

WEIGHT OF THE IRON IN STATOR TEETH   = 4.79689E-03 Kg

WEIGHT OF THE IRON IN STATOR CORE   = 2.270497E-02 Kg

WEIGHT OF THE IRON IN ROTOR   = 3.230595E-02 Kg

WEIGHT OF THE STATOR WINDINGS   = 2.716672E-03 Kg

WEIGHT OF THE ROTOR WINDINGS   = 630.3955 Kg

                COST OF THE MATERIALS USED

SPECIFIC COST OF IRON PER Kg.   =Rs. 40

SPECIFIC COST OF STATOR COPPER PER Kg.   =Rs. 110

SPECIFIC COST OF ROTOR COPPER PER Kg.   =Rs. 15

TOTAL COST OF ACTIVE MATERIALS   =Rs. 9458.624

                      PERFORMANCES

TOTAL LOSSES   = 1875.339 Watts

OUTPUT   = 11 KW

INPUT   = 12.87534 KW

EFFICIENCY   = 85.43464 %

SLIP   = 2.393418E-02

DESIGN SHEET

KW- 110   PHASE- 3   FREQUENCY 50 Hz

VOLTAGE- 3300 Volts   CONNECTION-DELTA   TYPE-CAGE

RATING

RATING OF THE MACHINE   = 110 Kw

SUPPLY VOLTAGE   = 3300 Volts

SUPPLY FREQUENCY   = 50 Hz

NUMBER OF PHASES   = 3

EFFICIENCY OF THE MOTOR   = .9036576

POWER FACTOR   = .86

NUMBER OF POLES   = 10

SPEED OF THE MOTOR   = 600 Rpm

KVA INPUT   = 140.5571 KVA

STATOR WINDING FACTOR   = .955

LOADING

SPECIFIC MAGNETIC LOADING   = .48 Wb/Sq.Mtr

SPECIFIC ELECTRIC LOADING   = 28000 A/Mtr

OUTPUT COEFFICIENT   = 141.1872

D^2*L   = 9.955372E-02 Cubic Mtr

MAIN DIMENSIONS

DIAMETER OF THE CORE   = .583001 Mtrs

LENGTH OF THE CORE   = .2928997 Mtrs

NET IRON LENGTH   = .2456097 Mtrs

POLE PITCH   = .1830623 Mtrs

STATOR

TYPE OF WINDING	=SINGLE LAYER MUSH
CONNECTION	=DELTA
PHASE VOLTAGE	= 3300 Volts
FLUX PER POLE	= 2.573707E-02 Wb
TURNS PER PHASE	= 604
NUMBER OF STATOR SLOTS	= 150
SLOTS PER POLE PER PHASE	= 5
COIL SPAN	= 15 Slot
DISTRIBUTION FACTOR	= .9567206
PITCH FACTOR	= 1
WINDING FACTOR	= .9567206
SLOT PITCH	= 1.220415E-02 Mtrs
CONDUCTORS PER SLOT	= 24
BARE CONDUCTOR DIAMETER	= 1.063198 mm
CONDUCTOR OVERALL DIAMETER	= 1.158198 mm
AREA OF THE CONDUCTOR	= 1.774711 Sq.mm
CURRENT DENSITY	= 4 A/Sq.mm
LENGTH OF MEAN TURN	= 1.246843 Mtr
STATOR RESISTANCE PER PHASE	= 8.852268 Ohms
STATOR COPPER LOSS	= 5353.17 Watts
DEPTH OF THE STATOR CORE	= 3.742445E-02 Mtr
OUTER DIAMETER OF STATOR LAMINATIONS	= .7174434 Mtr

ROTOR

LENGTH OF AIR GAP	= 1.026464 mm
DIAMETER OF ROTOR	= .580948 Mtr

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TYPE OF WINDING	=SQUIRREL CAGE
NUMBER OF SLOTS	= 155
SLOTS PER POLE PER PHASE	= 5
WINDING FACTOR	= .9567206
SLOT PITCH	= 1.176888E-02 Mtr
BAR CURRENT	= 455.2045 Amps
AREA OF THE BAR	= 91 Sq.mm
LENGTH OF THE BAR	= .3338997 Mtrs
CURRENT DENSITY	= 5 A/Sq.mm
RESISTANCE OF EACH BAR	= 6.689301E-05 Ohms
END RING CURRENT	= 2247.028 Amps
AREA OF THE END RING	= 449 Sq.mm
MEAN DIAMETER OF THE END RING	= .353748 mm
RESISTANCE OF EACH RING	= 1.6545E-05 Ohms
TOATL ROTOR COPPER LOSS	= 2315.527 Watts
DEPTH OF THE ROTOR CORE	= 3.742445E-02 Mtr

LOSSES

TOTAL mmf REQUIRED	= 757.5905 A
MAGNETISING CURRENT PER PHASE	= 5.64557 Amps
MAGNETISING REACTANCE	= 584.5292 Ohms
CORE LOSS	= 7 Watts
TOTAL IRON LOSSES	= 2958.817 Watts
FRICTION AND WINDAGE LOSSES	= 1100 Watts
NO LOAD LOSSES	= 4058.817 Watts
TOTAL COPPER LOSSES	= 7668.697 Watts
LOSS COMPONENT	= .4099815 Amps
NO LOAD CURRENT PER PHASE	= 5.660436 Amps

NO LOAD POWER FACTOR   = 7.242931E-02

STATOR TEMPERATURE RISE   = 75.30721 Degrees

ROTOR TEMPERATURE RISE   = 72.139 Degrees

WEIGHT OF THE MATERIALS USED

WEIGHT OF THE IRON IN STATOR TEETH   = 3.541185E-02 Kg

WEIGHT OF THE IRON IN STATOR CORE   = .1540711 Kg

WEIGHT OF THE IRON IN ROTOR   = .3207992 Kg

WEIGHT OF THE STATOR WINDINGS   = 9.508902E-03 Kg

WEIGHT OF THE ROTOR WINDINGS   = 5425.032 Kg

COST OF THE MATERIALS USED

SPECIFIC COST OF IRON PER Kg.   =Rs. 40

SPECIFIC COST OF STATOR COPPER PER Kg.   =Rs. 110

SPECIFIC COST OF ROTOR COPPER PER Kg.   =Rs. 15

TOTAL COST OF ACTIVE MATERIALS   =Rs. 81396.93

PERFORMANCES

TOTAL LOSSES   = 11727.51 Watts

OUTPUT   = 110 KW

INPUT   = 121.7275 KW

EFFICIENCY   = 90.36576 %

SLIP   = 2.041631E-02

LIST OF VARIABLES USED FOR THREE PHASE INDUCTION MOTOR

AB-   Area of the bar in Sq.mm.

ABP-   Area of the bar provided in Sq.mm.

AC-   Specific electric loading in AT/Mtr.

ACS-   Area of the stator core in Sq.mtr.

AE-   Area of the end ring in Sq.mm.

ALPH-   Chording angle.

AMEW-   Permeability of free space in H/M.

AOSC-   Area of the stator core in Sq.mtr.

ARERC1-   Area of the rotor conductor in Sq.mtr.

ART-   Area of the rotor teeth in Sq.mtr.

AS-   Ange between slots.

ASC1-   Area of the conductor provided in Sq.mtr.

ASR-   Area of the stator conductor in Sq.mtr.

AST-   Area of the stator teeth in Sq.mtr.

ATG-   Air gap m.m.f.

ATPM-   Ampere turns per metre.

ATPM1-   Ampere turns per metre.

ATRC-   Ampere turns in rotor core.

ATRT-   Ampere turns in rotor teeth.

ATSC-   Ampere turns in stator core.

ATST-   Ampere turns in stator teeth.

AX-   Ratio of stator slot depth to width.

BAV-   Specific magnetic loading in Wb/Sq.mtr.

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BCS-   Flux density in stator core in Wb/Sq.mtr.

BTRS-   Flux density in rotor teeth considering saturation.

BTRS1-   Average flux density in rotor in Wb/Sq.mtr.

BTSS-   Flux density stator teeth in Wb/Sq.mtr.

BTSS1-   Average flux density in stator in Wb/Sq.mtr.

C-   Power factor

CCFVD-   Cooling coefficient for ventilating ducts.

CCOFIS- Cooling coefficient for inner surface of stator.

CCORS-   Cooling coefficient for outside rotor surface.

CCOS-   Cooling coeeficient for outside stator surface.

CD-   Stator current density in A/Sq.mm.

CER-   Copper loss in end rings in Watts.

CGCD-   Carters' gap coefficient for ducts.

CGCR-   Carters' gap coefficient for rotor.

CGCS-   Carters' gap coefficient for stator.

CIFL-   Full load current in Amps.

CIL-   Loss component of no load current per phase.

CIM-   Magnetising current per phase in Amps.

CINL-   No load current per phase in Amps.

CIST-   Starting current in Amps.

CO-   Output coefficient

CORLOSS-Core loss in Watts.

CS-   Coil span.

CS1-   Provided coil span.

2

D-   Diameter of the stator core in metre.

DB1-   Depth of the rotor bar in mm.

DCR-   Depth of the rotor core in metre.

DCS-   Depth of the stator core in metre.

DE-   Depth of the end ring in mm.

DENCO-   Density of copper.

DENIR-   Density of iron.

DIE-   Inner diameter of the end ring in mm.

DO-   Stator lamination outer diameter in metre.

DOE-   Outer diameter of the end ring in mm.

DR-   Rotor diameter in metre.

DRB-   Depth of the rotor bar in mm.

DRS-   Depth of the rotor slot in mm.

DS-   Diameter of the stator conductor in mm.

DSL-   Product of D^2 and L.

DS1-   Diameter of the bare conductor in mm.

DS11-   Diameter of the bare conductor in mm.

DSS-   Depth of the stator slot in metre.

E-   Efficiency of the motor.

EAGL-   Effective air gap length in mm.

F-   Supply frequency in Hz.

FC-   Flux in the core in Wb.

FD-   Flux density in the core in Wb/Sq.mtr.

FLUX-   Flux per pole in Wb.

FWL-   Friction and windage losses in Watts.

GCFD-   Gap contraction factor for ventilating ducts.

GCFR-   Gap contraction factor for rotor slots.

GCFS-   Gap contraction factor for stator slots.

GCFT-   Total gap contraction factor.

IB-   Bar current in Amps.

IE-   End ring current in Amps.

IDRL-   Inner diamter rotor of lamination.

IS-   Stator current per phase in Amps.

KD-   Winding distribution factor.

KI-   Stacking factor.

KP-   Pitch factor.

KW-   Stator winding factor.

KWS-   Stator winding factor.

L-   Length of the core in mtrs.

LB-   Length of the each bar in mtrs.

LDFISS- Loss dissipated from inner stator surface in W/De.C

LDFOS- Loss dissipated from outer surface in Watts/Deg.C.

LG-   Length of the air gap.

LI-   Gross length.

LMT-   Length of the mean turn.

LT-   Ratio of pole arc to pole pitch.

MDE-   Mean diameter of the end ring in mm.

MFD-   Mean flux density in Wb/Sq.mtr.

MFDTH- Maximum flux density in Wb/Sq.mtr.

MPSC-   Mean periphery of stator core in mtrs.

MWST-	Mean width of stator teeth or stator slots.
N-	Speed of the machine in Rpm.
NCD-	Number of conductors in depthwise.
NCW-	Number of conductors in widthwise.
NS-	Synchronous speed in Rps.
NWS-	Number of wires in slots.
OCYSR-	Outside cylinderical surface of rotor in Sq.mtr.
ODC-	Over all diameter of the conductor.
OLR-	Over hang leakage reactance in Ohms.
OP-	Permeance of over hang portion.
P-	Number of poles.
PEREFF-	Percentage efficiency of the machine
PERISPD-	Peripheral speed.
PFFL-	Full load power factor.
PENL-	No load power factor.
PG-	Phase group.
PH-	Number of phases.
PM-	Resistance due to core loss in Ohms.
PRS-	Specific slot permeance for rotor slots.
PSP-	Phase winding starting point.
PSSS-	Specific slot permeance for stator slots.
Q-	H.P rating.
R-	Rating of the machine in Kw.
RB-	Resistance of the rotor bar in Ohms.
RCD-	Rotor current density in Amp/Sq.mm.

RCPATH- Length of the flux path through rotor core in mtrs.

RE-   Resistance of the end ring

RGSI-   Reluctance of air gap with slotted armature.

RS-   Stator resistance per phase in Ohms.

RTRISE- Rotor temperature rise in Degrees.

SATRT-   m.m.f. per metre for rotor teeth.

SATSC-   m.m.f per metre for stator and rotor core.

SATST-   m.m.f. per metre for stator teeth.

SCD-   Cooling coefficient for ventilating ducts.

SCLP-   Length of the conductor per phase in mtr.

SCLOS-   Total stator copper loss in Watts.

SCMT-   Slip at maximum torque.

SCPATH- Length of the flux path through stator core in mtr.

SLOS-   Total stator power loss in Watts.

SPCIR-   Specific cost of iron in Rs.

SPCOWM- Specific cost of stator copper per Kg.in Rs.

SPLC-   Specific iron loss in stator core in W/Kg.

SPLST-   Specific iron loss in W/Kg.

SPORCW- Specific cost of rotor copper per Kg. in Rs.

SPP-   Slots per pole per phase.

SR-   Number of rotor slots.

SRSR-   Stator referred rotor resistance per phase at
         the time of starting.

SS-   Number of stator slots.

SSD-   Cooling coefficient for ventilating ducts.

SSO-   Outer cylinderical stator surface.

STATOQ-   Starting torque. ✓

STCB-   Ratio of the starting current to full load current.

STRIS-   Stator temperature rise in Degrees.

SVD-   Surface of ventilating ducts in Sq.mtr.

TAPP-   Tooth area per pole.

TAT-   Total m.m.f. required.

TCB-   Total copper loss in bars in Watts.

TCLOS-   Total copper loss in Watts.

TE-   Thickness of the end ring.

TIL-   Total iron loss in Watts.

TLDS-   Total loss dissipation.

TLIST-   Total iron loss in stator teeth.

TMAX-   Pull out torque. ✓

TMAXPU-   P.U. Maximum torque.

TOTIC-   Total iron cost in Rs.

TOTC-   Total cost active material in Rs.

TRCL-   Total rotor copper loss in Watts.

TS1-   Turns per phase.

TSC1-   Number of conductors per slot.

TWM-   Mean width of the stator teeth in mtr.

V-   Supply voltage in volts.

WETCI-   Weight of the iron in stator core in Kg.

WETRI-   Weight of the iron in rotor in Kg.

WETRW-   Weight of the rotor winding in Kg.

WETST-   Weight of the stator teeth in Kg.

WETSW-   Weight of the stator winding in Kg.

WRS-   Width of the rotor slot.

WRT-   Width of the rotor teeth.

WSO-   Widht of the slot opening.

WSS-   Width of the stator slot.

WTCI-   Weight of the iron in stator core in Kg.

WTS-   Width of the stator teeth.

WTST-   Weight of the stator teeth in Kg.

XL-   Total leakage reactance per phase in Ohms.

XM-   Magnetising reactance in Ohms.

XR-   Total rotor leakage reactance inOhms.

XS-   Total stator leakage reactance in Ohms.

XZ-   Zig-zag leakage reactance in Ohms.

YSR-   Rotor slot pitch.

YSS-   Stator slot pitch.

YSS1-   Contractor slot pitch in mtrs.

YSSR-   Slot pitch at the root of the teeth.

ZSS-   Total number of stator conductors.

EPILOGUE

" If I can see a little beyond others, if it is

by standing on the shoulders of giants ".

Newton has himself said that he was sceing 'a little beyond' ordinary men,

it is an amusing exercise to strength our imagination to guage what an amount

of knowledge lies beyond, waiting to be discovered and uncovered. Every

bit of scientific work, fundamental or applied has got its own use and

its own effect. For, has Einstein not said 'we are engaging Ourselves in

the noblest work conceivable by mankind, if it is breaking yet another

fragment on the frontiers of beauty?'. This little thesis, this tiny bit of

work, comparing the vastness of the gaint's studies made in science already,

claims its credit that way.

Now in this crucial state of affairs one may really

wonder as to whether this sort of design, may serve the purpose for which

it is intended to All the same this technique gives us an insight into the

magnitude of work, which lies ahead of us, in mobilizing our existing resources

tomake a headway towards a quality improvement programme. With this

theoretical design given in this text, the extend to which this design is

versatile can be made only when a competitive and compartitive study is

made on the existing machines of similar ratings, Unfortunately this is beyond

the s.ope of this project work.

FUTRE DEVELOPMTNES:

The designed machine canbe optimized using any one of the standard optimization technique. The suitability of an algorithm for solving an optimizination problem mostly depends on the types of functions involved and on the ease with which the first and / or second derivatives. of the functions can be computed. It is more convenient to formulate most engineering problems using a non - linear programming method and satisfy the constraints by following the penalty function approach.

NON LINEAR PROGRAMMING PROBLEM:

The non - linear programming (NLP) problem can be stated as follows:-

Find the specific values x_1, x_2...., x_n, if they exist, of the variables x_{10}, x_2,..., x_n.

that will satisfy the inequality constraints,

g_i $(x_1, x_2, ... x_n)$ 0   (i = 1,2   ....,n) and the equality constraints

$h_j(x_1, x_2, ... x_n)$ = 0 (j = m+1, m+2...., k) and minimize the objective function.

$$F (x_1, x_2, ... x_n)$$

Over all values of $x_1, x_2, ... x_n)$ satisfying constraints. Here, g_i, h_j and F are the numerical functions of the variables $x_1, x_2, ... x_n$ and are defined for all finite values of the variables. F is called the object function. Atleast one of the functions in the above expressions must be nonlinear.

In general the objective and constraint functions for an engineering optimzation problem are highly non linear. Therefore it may not be possible to obtain a solution using the linear programming technique. Hence, such a problem is required to be solvedby using NLP.

EXTERIOR PENALTY FUNCTION METHOD:

Consider the following NLP problem:

Find $x = (x_1, x_2, ... x_n)$ such that $F(x)$ is a minimum,

$g_i(x)$ 0   for $i = 1,2,,....m$, and x_i 0   for $i = 1,2...n$.

In the exterior penalty function method, the augmented function p is formulated as,

$$P(x,r) = F(x), + r \sum_{i=1}^{m} [g_i(x)]^q \quad r \quad 0,$$

Where $[g_i(x))[$ is defined as max $[g_i(x),0[$. The popular value of q is a 2 although other values are possible,.

Starting with x_1, and r_1 minimize $P(x,r_1)$ using any of the unconstrained optimization techniques.

Let x_2 be the resulting point. Now, a new function P is formed with $r_2 = (r_1,$ 1,   Such that

$$P(X,r_2) = F(x) + r_2 \sum_{i=1}^{m} [g_i(x))[^q$$

With x_2 as the initial point, minimize P (x,r_2) at x_3, and so on. thus as r_k , the number of minimizations of the function P tends to infinity, and it can be proved that the minimum of P tends to the minimum of F,

$$\underset{K}{\min} \; P\,(x,r_k) = \min\; F(x).$$

If P is a convex function (ie,) F and gi are convex, then the minimum obtained is the global minimum.

Simplex method is the unconstrained technique used. here. Simplex method should not be confused with the simplex method used for solving LP problem. It utilizes a regular geometric figure (called a simplex). Consisting of (n+1) vertices for an n - variable optimization problem.

CHAPTER - X

CONCLUSIONS

A computer program has been developed for the design of three phase squirrel cage induction motors. The program is written in basic language. The program can be used to design motors of any capacity ranging from a few watts to several watts.

A computer simulation results for five different capacity motors are given. The computational time taken by AURELEC computer system is   seconds and the memory requirement is

It was proposed to develop a computer program for optimal design of three phase induction motors. The objective of the optimization was to minimise the cost of the motor. Due to lack of time, the iterative technique for optimization could not be incorporated in the computer program.

The iterative technique would normally take more computer time. The computer time can be reduced by using a non-limear optimization technique. Further work can be done to incorporate in the program a non-.linear optimization procedure to minimize the cost of the motor.

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