Scilab Textbook Companion for Special Electrical Machines by S. P. Burman[1]

Created by
Mohd. Asif
B.Tech
Electronics Engineering
Uttarakhand Tech. University
College Teacher
Mohd. Rijwan
Cross-Checked by
Lavitha Pereira

July 31, 2019

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: Special Electrical Machines

Author: S. P. Burman

Publisher: S. K. Katariya & Sons, New Delhi

Edition: 2

Year: 2013

ISBN: 978-93-5014-262-2

Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 1

Poly Phase AC Machines

Scilab code Exa 1.1.s `Full Load Slip`

```
// Example 1.1 Page: 41

clear; clc; close;

format('v',6);
// Given data
P=4;//No. of poles
f=50;//in Hz
N=1410;//in rpm

//Calculations
Ns=120*f/P;//in r
disp(Ns,"Synchronous speed in rpm : ");
S=(Ns-N)/Ns;//Full load slip
S=S*100;//in %
disp(S,"Full load slip in % : ");
```

Scilab code Exa 1.1 `Ratio of Torque`

```
// Example 1.1

clear; clc; close;

format('v',6);
// Given data
Zinner=0.01+0.5*%i;//Impedence at standstill of
    inner cage in ohm
Zouter=0.05+0.1*%i;//Impedence at standstill of
    outer cage in ohm

//Calculations
//Part (a) : at starting
R1=real(Zinner);//in ohm
R2=real(Zouter);//in ohm
X1=imag(Zinner);//in ohm
X2=imag(Zouter);//in ohm
//Formula : Ts=3/ws*V_dash^2*R2/(R2^2+X2^2)
TsoBYTsi=(R2/(R2^2+X2^2))/(R1/(R1^2+X1^2))
disp(TsoBYTsi,"Part(a) Ratio of Torque : ");
//Part(b) : slip =5%
S=5/100;//slip
//Formula : T=3/ws*V_dash^2*(R2/S)^2/((R2/S)+X2^2)
ToBYTi=((R2/S)/((R2/S)^2+X2^2))/((R1/S)/((R1/S)^2+X1
    ^2))
disp(ToBYTi,"Part (b) Ratio of Torque : ");
```

Scilab code Exa 1.2 Speed of Motor

```
// Example 1.2

clear; clc; close;

format('v',6);
// Given data
```

```
P=2;//No. of poles
f=50;//in Hz
S=2;//in %


//Calculations
S=S/100;//unitless
Ns=120*f/P;//in rpm
N=Ns*(1-S)
disp(N,"Speed of motor in rpm : ");
```

Scilab code Exa 1.3 `Frequency of EMF`

```
// Example 1.3

clear; clc; close;

format('v',6);
// Given data
P=4;//No. of poles
f=50;//in Hz
N=1470;//in rpm

//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//Slip
fr=S*f;//induced emf frequency in Hz
disp(fr,"Induced emf frequency in Hz : ");
```

Scilab code Exa 1.4 `Frequency and magnitude of emf`

```
// Example 1.4

```

```
clear; clc; close;

format('v',6);
// Given data
P=4;//No. of poles
f=50;//in Hz
K=1/2;//rotor to stator turns
N=1455;//in rpm
E1_line=415;//in volt


//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//Slip
fr=S*f;//induced emf frequency in Hz
disp(fr,"(i) Frequency of rotor emf in running
   condition in Hz : ");
N2BYN1=K;//rotor to stator turns
N1BYN2=1/K;//stator to rotor turns
E1ph=E1_line/sqrt(3);//
//Formula : E2ph/E1ph=K
E2ph=E1ph*K;//in volt
disp(E2ph,"(ii) Rotor induced emf at standstill in
   volt : ");
E2r=S*E2ph;//in volt
disp(E2r,"(iii) Rotor induced emf at running
   condition in volt : ");
```

Scilab code Exa 1.5 Rotor current and power factor

```
// Example 1.5

clear; clc; close;

format('v',6);
```

```
// Given data
P=4;//No. of poles
f=50;//in Hz
R2=0.2;//in ohm
X2=1;//in ohm
N=1440;//in rpm
E2_line=120;//in volt


//Calculations
E2ph=E2_line/sqrt(3);//
cosfi_2=R2/sqrt(R2^2+X2^2);//lagging power factor
I2=E2ph/sqrt(R2^2+X2^2);//in Ampere/phase
disp(cosfi_2,"(i) Rotor power factor(lagging) : ");
disp(I2,"(i) Rotor Current in Ampere per phase: ");
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//Slip
cosfi_2r=R2/sqrt(R2^2+(S*X2)^2);//lagging power factor
I2r=S*E2ph/sqrt(R2^2+(S*X2)^2);//in Ampere
disp(cosfi_2r,"(ii) Rotor power factor(lagging) : ");
disp(I2r,"(ii) Rotor Current in Ampere : ");
```

Scilab code Exa 1.6 `Torque developed`

```
// Example 1.6

clear; clc; close;

format('v',6);
// Given data
P=4;//No. of poles
f=50;//in Hz
R2=0.1;//in ohm
```

```
X2=1;//in ohm
N=1440;//in rpm
E1_line=400;//in volt
Kdash=2;//stator turns by rotor turns

//Calculations
K=1/Kdash;//rotor turns by stator turns
Ns=120*f/P;//in rpm
E1ph=E1_line/sqrt(3);//
//Formula : E2ph/E1ph=K
E2ph=E1ph*K;//in volt
S=(Ns-N)/Ns;//Slip
ns=Ns/60;//synchronous speed in rps
T=3/(2*%pi*ns)*(S*E2ph^2*R2)/(R2^2+(S*X2)^2);//in N-
    m
disp(T,"Torque devloped on full load in N-m : ");
```

Scilab code Exa 1.7 Torque Slip and Speed

```
// Example 1.7

clear; clc; close;

format('v',6);
// Given data
P=4;//No. of poles
f=50;//in Hz
Kdash=4;//stator turns by rotor turn
R2=0.01;//in ohm
X2=0.1;//in ohm
E1_line=400;//in volt

//Calculations
K=1/Kdash;//rotor turns by stator turns
Ns=120*f/P;//in rpm
```

```
E1ph=E1_line/sqrt(3);//
//Formula : E2ph/E1ph=K
E2ph=E1ph*K;//in volt
//(i) at start S=1
ns=Ns/60;//in rps
K=3/2/%pi/ns;
Tst=K*E2ph^2*R2/(R2^2+X2^2);//in N-m
disp(Tst,"(i) Starting Torque in N-m : ");
//part (ii)
Sm=R2/X2;//slip for max torque
disp(Sm*100,"(ii) Slip at which max torque devloped
    in % : ");
//Part (iii)
N=Ns*(1-Sm);//in rpm
disp(N,"(iii) Speed at which max torque occur in rpm
     : ");
//Part (iv)
Tm=K*E2ph^2/2/X2;//in N-m
disp(Tm,"Maximum  torque in N-m : ");
//Part (v)
Sf=4;//in %
Sf=Sf/100;//slip
Tfl=K*Sf*E2ph^2*R2/(R2^2+(Sf*X2)^2);//in N-m
disp(Tfl,"(v) Full load Torque devloped in N-m : ");
```

Scilab code Exa 1.8 Ratio of Torque

```
// Example 1.8

clear; clc; close;

format('v',6);
// Given data
P=24;//No. of poles
f=50;//in Hz
```

```
R2=0.016;//in ohm
X2=0.265;//in ohm
N=247;//in rpm

//Calculations
Ns=120*f/P;//in rpm
Sf=(Ns-N)/Ns;//full load slip
Sm=R2/X2;//max slip
Tfl_BY_Tm=2*Sm*Sf/(Sm^2+Sf^2);//unitless
disp(Tfl_BY_Tm,"Ratio of full load torque to max
    torque : ");
Tst_BY_Tm=2*Sm/(1+Sm^2);//unitless
disp(Tst_BY_Tm,"Ratio of starting torque to max
    torque : ");
```

Scilab code Exa 1.9 Maximum Torque

```
// Example 1.9

clear; clc; close;

format('v',7);
// Given data
R2=0.04;//in ohm
X2=0.2;//in ohm

//Calculations
R2dash=X2;//in ohm (for Tm=Tst)
//formula : R2dash=R2+rex
Rex=R2dash-R2;//in ohm/phase
disp(Rex,"(i) External resistance required in ohm/
    phase : ");
disp("For Tst=Tm/2, Tm=k*E2^2/2/X2 and Tst=k*E2^2*R2
    /(R2^2+X2^2)");
disp("This gives a polynomial for value of R2dash.")
```

```
;
P=[1 -4*X2 X2^2];//R2dash^2-4*X2*R2dash+X2^2=0
R2dash=roots(P);//in ohm
disp(R2dash,"Value of R2dash(ohm) are ")
disp(R2dash(2),"But R2dash cant be greater than X2, R2dash(ohm) is : ");
Rex=R2dash(2)-R2;//in ohm/phase
disp(Rex,"(ii) External resistance required in ohm/phase : ");
```

Scilab code Exa 1.10 `Rotor Copper Losses`

```
// Example 1.10

clear; clc; close;

format('v',8);
// Given data
f=50;//in Hz
P=8;//no. of poles
Tsh=190;//in N-m
fr=1.5;//in Hz
MechLoss=700;//in watts

//Calculations
S=fr/f;//Slip
Ns=120*f/P;//in rpm
N=Ns*(1-S);//in rpm
Pout=Tsh*2*%pi*N/60;//in watts
Pm=Pout+MechLoss;//in watts
//formula -: P2:Pc:Pm=1:S:1-S
Pc=Pm*S/(1-S);//in watts
disp(Pc,"Rotor Copper loss in watts : ");
```

Scilab code Exa 1.11 Full load Efficiency

```
// Example 1.11

clear; clc; close;

format('v',8);
// Given data
f=50;//in Hz
P=4;//no. of poles
Pin=50;//in kW
N=1440;//in rpm
StatorLoss=1000;//in watts
FrictionalLoss=650;//in watts

//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//Slip

N=Ns*(1-S);//in rpm
P2=Pin-StatorLoss/1000;//in KW
//formula -:  P2:Pc:Pm=1:S:1-S
Pc=S*P2;//in KW
Pm=P2-Pc;//in KW
Pout=Pm-FrictionalLoss/1000;//in KW
Eff=Pout/Pin*100;//in %
disp(Eff,"Full load efficiency in % : ");
```

Scilab code Exa 1.12 Slip Power Loss and Resistance

```
// Example 1.12

```

```
clear; clc; close;

format('v',8);
// Given data
f=50;//in Hz
phase=3;//no. of phase
P=4;//no. of poles
Tsh=300;//in N-m
Tlost=50;//in N-m
fr=120;//in cycles/min
fr=fr/60;//in Hz
I2r=60;//in Ampere/phase

//Calculations
S=fr/f;//slip
disp(S*100,"(i) Slip(%) : ");
Ns=120*f/P;//in rpm
N=Ns*(1-S);//in rpm
Pout=Tsh*2*%pi*N/60;//watts
disp(Pout/1000,"(ii) Net output Power(KW) : ");
FricLoss=Tlost*2*%pi*N/60;//in watts
Pm=Pout+FricLoss;//in watts
//formula-: P2:Pc:Pm=1:S:1-S
Pc=S*Pm/(1-S);//copper loss in Watts
PcPERphase=Pc/phase;//Copper loss per phase in watts
disp(PcPERphase,"(iii) Rotor copper loss per phase(
    watts) : ");
P2=Pc/S;//in watts
Eff=Pm/P2*100;//in %
disp(Eff,"(iv) Rotor efficiency in % : ");
//Formula : CuLossPerPhase=I2r^2*R2;//in watts
R2=PcPERphase/I2r^2;//in ohm/phase
disp(R2,"(v) Rotor resistance per phase(ohm/phase) :
    ");
```

Scilab code Exa 1.13 Power Losses and Efficiency

```
// Example 1.13

clear; clc; close;

format('v',6);
// Given data
Pout=25;//in KW
f=50;//in Hz
phase=3;//no. of phase
P=4;//no. of poles
N=1410;//in rpm
MechLoss=850;//in watts
StatLossBYCuLoss=1.17;
I2r=65;//in Ampere

//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//slip
Pm=Pout*1000+MechLoss;//in watts
disp(Pm,"Gross mechanical power devloped in watts :
   ");
//formula-: P2:Pc:Pm=1:S:1-S
Pc=S*Pm/(1-S);//copper loss in Watts
disp(Pc,"Rotor Copper Losses in watts : ");
R2=Pc/phase/I2r^2;//in ohm/phase
disp(R2,"Rotor resistance per phase in ohm ; ");
StatorLoss=1.7*Pc;//in watts
P2=Pc/S;//in Watts
Pin=P2+StatorLoss;//in watts
Eff=Pout*1000/Pin*100;//in %
disp(Eff,"Full laod Efficiency in % : ");
```

Scilab code Exa 1.14 Torque Losses and Efficiency

```
// Example 1.14

clear; clc; close;

format('v',7);
// Given data
Pout=24;//in KW
P=8;//no. of poles
N=720;//in rpm
VL=415;//in volt
IL=57;//in Ampere
f=50;//in Hz
phase=3;//no. of phase
cosfi=0.707;//power factor
MechLoss=1000;//in watts
Rs=0.1;//in ohm/phase

//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//slip
Pm=Pout*1000+MechLoss;//in watts
//formula -:  P2:Pc:Pm=1:S:1-S
//Pc=S*Pm/(1-S);//copper loss in Watts
Tsh=Pout*10^3/(2*%pi*N/60);//in N-m
disp(Tsh,"Shaft Torque in N-m : ");
T=Pm/((2*%pi*N/60));//in N-m
disp(T,"Gross torque devloped in N-m : ");
Pc=S*Pm/(1-S);//copper loss in Watts
disp(Pc,"Rotor Cu losses in watts : ");
P2=Pc/S;//in watts
Pin=sqrt(3)*VL*IL*cosfi;//in watts
Is=IL;//stator current per phase in Ampere
StatorCuLoss=3*Is^2*Rs;//in watts
disp(StatorCuLoss,"Stator Copper losses in watts : "
   );
StatorLosses=Pin-P2;//in watts
StatorIronLoss=StatorLosses-StatorCuLoss;//in watts
disp(StatorIronLoss,"Stator Iron losses in watts : "
```

```
    );
Eff=Pout*10^3/Pin*100;//in %
disp(Eff,"Efficiency in % : ");
```

Scilab code Exa 1.15 Maximum Torque and Speed

```
// Example 1.15

clear; clc; close;

format('v',8);
// Given data
Poles=12;//no. of poles
V1=420;//in volt
f=50;//in Hz
r1=2.95;//in watts
x1=6.82;//in watts
r2dash=2.08;//in watts
x2dash=4.11;//in ohm/phase
ImLine=6.7;//in Ampere
TcoreLoss=269;//in watts
S=3;//slip in %

//Calculations
S=S/100;//slip
Im=ImLine/sqrt(3);//in Ampere
Im_bar=Im*exp(%i*(-%pi/2))*(r1+%i*x1);//in Ampere
//V1=(E1+real(Im_bar))+imag(Im_bar)
//Equating magnitude of both sides gives a
    polynomial for E1
P=[1 2*real(Im_bar) abs(Im_bar)^2-V1^2];
E1=roots(P);
E1=E1(2);//discarding -ve value
Xo=E1/Im;//in ohm
//Zeq=Xo*exp(%i*(%pi/2))*(r2dash/S)/(%i*Xo+%i*x2dash
```

```
+r2dash/S);
Zeq=%i*Xo*(r2dash/S+%i*x2dash)/(%i*Xo+%i*x2dash+r2dash/S);
Zin=r1+%i*x1+Zeq;//in ohm
I1=V1/Zin;//in Ampere
disp("Magnitude is "+string(abs(I1))+" & angle in degree is "+string(atand(imag(I1),real(I1))));
cosfi=cosd(atand(imag(I1)/real(I1)));//lagging power factor
disp(cosfi,"Power factor(lagging) : ");
I2r_dash=I1*(%i*Xo)/(r2dash+%i*(Xo+x2dash));//in Ampere
//disp(I2r_dash,"Equivalent rotor current in Ampere : ");
disp("Magnitude is "+string(abs(I2r_dash))+" & angle in degree is "+string(atand(imag(I2r_dash),real(I2r_dash))));
Ns=120*f/Poles;//in rpm
T=9.55*3*real(I2r_dash)^2*r2dash/S/Ns;//in N-m
disp(T,"Torque devloped in N-m : ");
Zth=(r1+%i*x1)*%i*Xo/((r1+%i*x1)+%i*Xo);//in Ohm
Rth=real(Zth);//in ohm
Xth=imag(Zth);//in ohm
Vth=V1*(%i*Xo)/(r1+%i*(Xth+Xo));//in Volt
Ws=(2*%pi*Ns/60);//in rad/sec
Tm=(3/Ws)*0.5*real(Vth)^2/(Rth+sqrt(Rth^2+(Xth+x2dash)^2));//in N-m
disp(Tm,"Maximum torque devloped in N-m : ");
Sm=r2dash/sqrt(Rth^2+(Xth+x2dash)^2);//slip
Nm=Ns*(1-Sm);//
disp(Nm,"Speed at maximum torque in rpm : ");
//Answer for rotor equivalent Current and Torque developed is wrong in the book.
```

Scilab code Exa 1.16 `Line current Torque and Efficiency`

```
// Example 1.16

clear; clc; close;

format('v',7);
// Given data
V=440;//in volt
P=8;//no. of poles
Pout=40;//in KW
f=50;//in Hz
phase=3;//no. of phase
R1=0.1;//in ohm
X1=0.4;//in ohm
R2dash=0.15;//Equivalent rotor resistance in ohm
X2dash=0.44;//Equivalent rotor reactance in ohm
I0=20*expm(%i*-acos(0.09));//in Ampere
N=727.5;//in rpm
MechLoss=1000;//in watts
CoreLoss=1250;//in watts

//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//slip
RLdash=R2dash*(1-S)/S
V1=V/sqrt(3);//in volt
R1e=R1+R2dash;//in ohm
X1e=X1+X2dash;//in ohm
I2rdash=V1/(R1e+RLdash+%i*X1e);//in Ampere
I1bar=I0+I2rdash;//in Ampere
InputCurrent=abs(I1bar);//in Ampere
InputPF=cosd(atand(imag(I1bar),real(I1bar)));//
disp(InputPF,InputCurrent,"(i) Input Current in
    Ampere & PF(lagging) are : ");
T=3*abs(I2rdash)^2*R2dash/S/(2*%pi*Ns/60);//in N-m
disp(T,"(ii) Torque Developed in N-m : ") ;
P2=3*abs(I2rdash)^2*R2dash/S;//in Watts
//Formula : P2:Pc:Pm=1:S:1-S
Pm=(1-S)*P2;//in Watts
```

```
TotPout=Pm-MechLoss;//in watts
disp(TotPout,"(iii) Output power in Watts : ");
TotCuLoss=3*abs(I2rdash)^2*R1e;//in watts
Eff=TotPout/(TotPout+TotCuLoss+CoreLoss+MechLoss)*100;//in %
disp(Eff,"(iv) Efficiency in % : ");
```

Scilab code Exa 1.17 `Maximum Power and Slip`

```
// Example 1.17

clear; clc; close;

format('v',6);
// Given data
Z1=0.07+%i*0.4;//in ohm
Z2dash=0.08+%i*0.2;//in ohm
V1_line=200;//in volt

//Calculations
R1=real(Z1);//in ohm
X1=imag(Z1);//in ohm
R2dash=real(Z2dash);//in ohm
X2dash=imag(Z2dash);//in ohm
R1e=R1+R2dash;//in ohm
X1e=X1+X2dash;//in ohm
Z1e=R1e+%i*X1e;//in ohm
Z1e_mag=abs(Z1e);//magnitude of Z1e in ohm
V1PerPhase=V1_line/sqrt(3);//in volt
Pout_max=3*V1PerPhase^2/2/(R1e+Z1e);//
S=R2dash/(R2dash+Z1e_mag);//
disp(S*100,"Slip in % : ")
```

Scilab code Exa 1.18 `Current from mains`

```
// Example 1.18

clear; clc; close;
format('v',6);
// Given data
P=4;//in poles
f=50;//in Hz
Pout=30;//in HP
VL=400;//in volt
Eta=0.8;//Efficiency
cosfi=0.75;//lagging power factor

//Calculations
Pout=Pout*735.5;//in Watts
Pin=Pout/Eta;//in Watts
//Formula : Pin=sqrt(3)*VL*IL*cosfi
IL=Pin/sqrt(3)/VL/cosfi;//in Ampere
disp(IL,"Current by the mains in ampere : ");
```

Scilab code Exa 1.19 `Slip Load Efficiency and Cycles`

```
// Example 1.19

clear; clc; close;
format('v',8);
// Given data
P=4;//in poles
Pout=37;//in HP
f=50;//in Hz
N=1425;//in rpm
MechLoss=3;//in HP
StatorLoss=2500;//in watts
VL=500;//in volt
```

```
cosfi=0.9;//power factor

//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//slip
disp(S,"(i) Slip is :  ");
Pout=Pout*735.5;//in Watts
MechLoss=MechLoss*735.5;//in Watts
Pin=Pout+MechLoss;//in Watts
//Formula : P2:Pc:Pin=1:5:1-S
Pc=(S/(1-S))*Pin;//in watts
disp(Pc,"(ii) Rotor Cu Loss in watts : ");
P2=Pc/S;//in Watts
Pin=P2+StatorLoss;//in watts
disp(Pin,"(iii) Total power input in watts : ");
Eta=Pout/Pin*100;//in %
disp(Eta,"(iv) Efficiency in % : ");
fr=S*f;//in Hz
fr=fr*60;//in cycles/min
disp(fr,"(v) No. of cycles per minute : ");
//Part (ii) & (iii) answer is wrong in the book.
```

Scilab code Exa 1.20 Current per phase

```
// Example 1.20

clear; clc; close;
format('v',7);
// Given data
E2line=60;//in Volt
R2=0.6;//in ohm
X2=4;//in ohm
Rx=5;//in ohm
Xx=2;//in ohm
S=4;//in %
```

```
//Calculations
E2ph=E2line/sqrt(3);//in volt
ZT=R2+%i*X2+Rx+%i*Xx;//
I2=E2ph/abs(ZT);//in Ampere
disp(I2,"(i) Rotor Current per phase in Ampere : ");
S=S/100;//slip
Z2r=R2+%i*S*X2;//in ohm
I2r=S*E2ph/abs(Z2r);//in Ampere
disp(I2r,"(ii) Rotor Current per phase in Ampere : "
   );
```

Scilab code Exa 1.21 Torque developed

```
// Example 1.21

clear; clc; close;
format('v',7);
// Given data
P=4;//no. of poles
f=50;//in Hz
P2=3000;//in watts

//Calculations
Ns=120*f/P;//in rpm
T=P2/(2*%pi*Ns/60);//in N-m
disp(T,"Torque Devloped in N-m : ");
T=T*(2*%pi*Ns/60);//in syn. Watt
disp(T,"Torque Devloped in syn. Watt : ");
```

Scilab code Exa 1.22 Required External Resistance

```
// Example 1.22
```

```
clear; clc; close;
format('v',7);
// Given data
E1Line=1000;//in volt
R2=0.01;//in ohm
X2=0.2;//in ohm
I2st=200;//in Ampere
ratio=3.6;//ratio of stator to rotor turns

//Calculations
K=1/ratio;//ratio of rotor to stator turns
E1ph=E1Line/sqrt(3);//in Volt
E2ph=K*E1ph;//in volt
//Let R2dash=R2+Rx
//Formula : I2st=E2ph/sqrt(R2dash^2+X2^2);
R2dash=sqrt((E2ph/I2st)^2-X2^2)
Rx=R2dash-R2;//in ohm
disp(Rx,"External resistance required per phase in
    ohm : ");
```

Scilab code Exa 1.23 `Torque and speed`

```
// Example 1.23

clear; clc; close;
format('v',7);
// Given data
VL=400;//in volt
E1Line=VL;//in volt
P=4;//no. of poles
S=5;//in %
f=50;//in Hz
R2=0.15;//in ohm
X2=1;//in ohm
```

```
ratio=2;//ratio of stator to rotor turns

//Calculations
S=S/100;//slip
E1ph=E1Line/sqrt(3);//in Volt
K=1/ratio;//ratio of rotor to stator turns
E2ph=K*E1ph;//in volt
Ns=120*f/P;//in rpm
ns=Ns/60;//in rps
T=(3/2/%pi/ns)*S*E2ph^2*R2/(R2^2+(S*X2)^2);//in N-m
disp(T,"(i) Total Torque devloped in N-m :");
Tm=(3/2/%pi/ns)*E2ph^2/2/X2;//in N-m
disp(Tm,"(ii) Maximum Torque in N-m :");
Sm=R2/X2;//maximum slip
N=Ns*(1-Sm);//in rpm
disp(N,"(iii) Speed at maximum torque in rpm : ");
```

Scilab code Exa 1.24 Speed Current and Efficiency

```
// Example 1.24

clear; clc; close;
format('v',7);
// Given data
VL=400;//in volt
f=50;//in Hz
P=6;//no. of poles
Z1=0.3+%i*0.4;//in ohm
Z2dash=0.2+%i*0.4;//in ohm
X0=20;//Magnetic reactance in ohm
R0=100;//resistance for core loss in ohm
S=4;//in %
StatorLoss=2;//in KW
MechLoss=2;//in KW
//Calculations
```

```
R1=real(Z1);//in ohm
R2dash=real(Z2dash);//in ohm
X1=imag(Z1);//in ohm
X2dash=imag(Z2dash);//in ohm
S=S/100;//slip
V1=VL/sqrt(3);//in volt
Ns=120*f/P;//in rpm
Ri=R2dash*(1-S)/S;//in ohm
R1e=R1+R2dash;//in ohm
X1e=X1+X2dash;//in ohm
I2rdash=V1/(R1e+Ri+%i*X1e);//in Ampere
Ic=V1/R0;//in Ampere
Im=V1/(%i*X0);//in Ampere
I0=(Ic+Im);//in Ampere
CoreLoss=Ic^2*R0;//Core loss per phase in Watts
I1=I0+I2rdash;//in Ampere
Istator=abs(I1);//in Ampere
cosfi=cosd(atand(imag(I1)/real(I1)));//lagging power
    factor

Pc=3*abs(I2rdash)^2*R2dash;//in Watts
//Here P2:P0:Pm=1:S:1-S
Pm=Pc*(1-S)/S;//in watts
Pout=Pm-MechLoss*1000;//in watts
StatorCuLoss=3*abs(I1)^2*R1;//in watts
TotLoss=CoreLoss*3+StatorCuLoss+Pc+MechLoss*1000;//
   in watts
Eff=Pout/(Pout+TotLoss)*100;//in %
N=Ns*(1-S);//in rpm
disp(N,"(a) Motor Speed in rpm : ");
disp(Istator,"(b) Stator current in Ampere : ");
disp(cosfi,"(c) Power factor lagging : ");
disp(Pout,"(d) Motor Output in Watts : ");
disp(Eff,"(d) Efficiency in % : ");
//Answer of Pout is wrong in the book.
```

Scilab code Exa 1.25 `Maximum Torque`

```
// Example 1.25

clear; clc; close;
format('v',7);
// Given data
V=440;//in volt
f=50;//in Hz
P=4;//no. of poles
X1=5.2;//in ohm
R2dash=1.2;//in ohm
X2dash=4.5;//in ohm

//Calculations
disp("Magnetic components not present. So, Rth=R1 & Xth=X1")
//Rth=R1;//in ohm
//Xth=X1;//in ohm
//Formula : R2dash/Sm=sqrt(X1^2+X2dash^2)
Sm=R2dash/(X1+X2dash);//Maximum Slip
I1=V/sqrt(3)/sqrt((R2dash/Sm)^2+(X1+X2dash)^2);//in Ampere
I2dash=I1;//in Ampere(Neglecting I0)
Ns=120*f/P;//in rpm
Tmax=3*I2dash^2*R2dash/Sm/2/%pi/Ns*60;//in N-m
disp(Tmax,"Maximum Torque in N-m ; ");
disp(Sm*100,"Maximum Slip in % : ");
```

Scilab code Exa 1.26 `Required External resistance`

```
// Example 1.26
```

```

clear; clc; close;
format('v',7);
// Given data
f=50;//in Hz
P=4;//no. of poles
X2=0.1;//in ohm
R2=0.02;//in ohm
//Tst=2/3*Tmax
TstByTm=2/3;//ratio

//Calculations
disp("Tst proportional to E2^2*R2dash/(R2dash^2+X2^2)");
disp("Tm proportional to E2^2/(2*X2)");
//formula : TstByTm=(E2^2*R2dash/(R2dash^2+X2^2))/(E2^2/(2*X2))
P=[TstByTm -2*X2 TstByTm*X2^2];//Polynomial for R2dash
R2dash=roots(P);//
R2dash=R2dash(2);//discarding higher value bcoc R2dash < X2
Rex=R2dash-R2;//in ohm
disp(Rex,"Extra resistance required in ohm : ");
```

Scilab code Exa 1.27 Speed and Ratio of Torque

```
// Example 1.27

clear; clc; close;
format('v',7);
// Given data
VL=3300;//in volt
f=50;//in Hz
P=10;//no. of poles
```

```
X2=0.25;//in ohm
R2=0.015;//in ohm
Sfl=2.5;//Slip in %

//Calculations
Ns=120*f/P;//in rpm
N=Ns*(1-Sfl/100);//in rpm
disp(N,"(1.) The speed of motor, N in rpm : ");
Sm=R2/X2;//Max Slip
Nm=Ns*(1-Sm);//Max speed in rpm
disp(Nm,"(2.) Speed of motor, Ns in rpm : ");
TmByTfl=Sm*R2/(R2^2+(Sm*X2)^2)*(R2^2+(Sfl/100*X2)^2)/(Sfl/100)/R2;//ratio
disp(TmByTfl,"(3.) Ratio of max torque to full load torque : ");
//Answer of 1st part is wrong in the book.
```

Scilab code Exa 1.28 `Rotor Current and Power`

```
// Example 1.28

clear; clc; close;
format('v',7);
// Given data
V0=400;//in volt
f=50;//in Hz
P=10;//no. of poles
R1=1.75;//in ohm
X1=5.5;//in ohm
R2dash=2.25;//in ohm
X2dash=6.6;//in ohm
I0=3.8;//in Ampere
W0=310;//in watts
S=4;//in %

```

```
//Calculations
S=S/100;//slip in ratio
//Formula : W0=sqrt(3)*V0*I0*cos_fi0
cos_fi0=W0/sqrt(3)/V0/I0;//power factor
sin_fi0=sind(acosd(cos_fi0));
Ic=I0*cos_fi0;//in Ampere
Im=I0*sin_fi0;//in Ampere
Vph=V0/sqrt(3);//in Volt
R0=Vph/Ic;//in ohm
X0=Vph/Im;//in ohm
Ns=120*f/P;//in rpm
RLdash=R2dash*(1-S)/S;//in ohm
R1e=R1+R2dash;//in ohm
X1e=X1+X2dash;//in ohm
I2rdash=Vph/(R1e+RLdash+%i*X1e);//in Ampere
disp(I2rdash,"Rotor Current in Ampere : ");
I0_bar=Ic-%i*Im;//in Ampere
I1_bar=I0_bar+I2rdash;//Supply current in Ampere
disp(I1_bar,"Supply Current in Ampere : ");
cosfi=cosd(atand(imag(I1_bar)/real(I1_bar)));//
    Lagging power factor
disp(cosfi,"Power factor(lagging) : ");
Pc=3*abs(I2rdash)^2*R2dash;//in watts
//Formula : P2:Pc:Pm=1:S:1-S
Pm=Pc*(1-S)/S;////in watts
disp(Pm,"Mechanical power devloped in N-m : ");
N=Ns*(1-S);//in rpm
w=2*%pi*N/60;//in rad/sec
T=Pm/w;//in N-m
disp(T,"Gross load tporque in N-m : ");
```

Scilab code Exa 1.29 Slip of Motor

```
// Example 1.29

```

```
clear; clc; close;
format('v',7);
// Given data
PA=12;//no. of poles
Ns=500;//in rpm
N=1440;//in rpm

//Calculations
//Formula : Ns=120*f/PA
f=Ns/120*PA;//in Hz
PM=4;//assumed for motor
Ns=120*f/PM;//in rpm(For motor)
S=(Ns-N)/Ns*100;//slip in %
disp(S,"Slip in % :");
```

Scilab code Exa 1.30 Required External Resistance

```
// Example 1.30

clear; clc; close;
format('v',7);
// Given data
R2=0.04;//in ohm
X2=0.2;//in ohm
TstByTm=50;//in %

//Calculations
Sm=1;//slip for max Torque
R2dash=Sm*X2;//in ohm
Rx=R2dash-R2;//in ohm
disp(Rx,"(i) External resistance required for max
    Torque(ohm ): ");
TstByTm=TstByTm/100;//in ratio
//Formula : Tst proportional to E2^2*R2dash/(R2dash
    ^2+X2^2)
```

```
//Formula : Tm Proportional to E2^2/2/X2
P=[TstByTm -2*X2 TstByTm*X2^2];//Polynomial for
    R2dash
R2dash=roots(P);//
R2dash=R2dash(2);//discarding higher value bcoc
    R2dash < X2
Rx=R2dash-R2;//in ohm
disp(Rx,"(ii) Extra resistance required for 50% max
    Torque at start(ohm) : ");
```

Scilab code Exa 1.31 Ratio of Torque

```
// Example 1.31

clear; clc; close;
format('v',7);
// Given data
f=50;//in Hz
P=8;//no. of poles
Sf=40;//in %
R2=0.001;//in ohm/phase
X2=0.005;//in ohm/phase

//Calculations
Sf=Sf/100;//slip
//Formula : T proportional to S*R2/(R2^2+(S*X2)^2)
Sm=R2/X2;//slip for max Torque
TmByTfl=Sm*R2/(R2^2+(Sm*X2)^2)*(R2^2+(Sf*X2)^2)/Sf/
    R2;//in ratio
disp(TmByTfl,"Ratio of max torque to full load
    torque : ");
Ns=120*f/P;//in rpm
N=Ns*(1-Sm);//in rpm
disp(N,"Speed for maximum torque in rpm : ");
```

Scilab code Exa 1.32 `Maximum Torque and Slip`

```
// Example 1.32

clear; clc; close;
format('v',7);
// Given data
f=50;//in Hz
P=4;//no. of poles
VL=400;//in volt
E2=100;//in volt
R2=50;//in milli ohm
X2=0.5;//in ohm

//Calculations
R2=R2*10^-3;//in ohm
Sm=R2/X2;//Maximum Slip
ns=(120*f/P)/60;//in rpS
Tmax=3/2/%pi/ns*Sm*E2^2*R2/(R2^2+(Sm*X2)^2);//in N-m
disp(Tmax,"Maximum Torque in N-m : ");
disp(Sm,"Slip at which Tmax occur : ");
```

Scilab code Exa 1.33 `Sm and Full load Slip`

```
// Example 1.33

clear; clc; close;

format('v',7);
// Given data
//Tst=100% of Tfl;//in %
//Tm=100% of Tfl;//in %
```

```
TstByTfl=100/100;//ratio
TmByTfl=200/100;//ratio

//Calculations
//Formula : T proportional to S*E2^2*R2/(R2^2+(S*X2)
    ^2)
//Formula : TstByTm=2*Sm/(Sm^2+1)
TstByTm=TstByTfl/TmByTfl;//Calculating TstByTm
P=[TstByTm -2 TstByTm];//Polynomial for Sm
Sm=roots(P);
Sm=Sm(2);//Discarding value > 1
disp(Sm*100,"Slip at which max Torque occurs(in %) :
    ");
//Formula : 1/TstByTm=(Sm^2+Sfl^2)/(2*Sm*Sfl)
P=[TstByTm -2*Sm Sm^2*TstByTm];//Polynomial for Sfl
Sfl=roots(P);
Sfl=Sfl(2);//Discarding value >= 1
disp(Sfl*100,"Full load slip (in %) : ");
```

Scilab code Exa 1.34 Find Torque

```
// Example 1.34

clear; clc; close;

format('v',7);
// Given data
P=8;//no. of Poles
f=50;//in Hz
Tm=150;//in N-m
N=650;//in rpm
R2=0.6;//in ohm
S=4;//in %

//Calculations
```

```
S=S/100;//Slip
Ns=120*f/P;//in rpm
Sm=(Ns-N)/Ns;//Maximum Slip
//Formula : T proportional to S*E2^2*R2/(R2^2+(S*X2)^2)
X2=R2/Sm;//in ohm
T=Tm*S*(R2^2+(Sm*X2)^2)/Sm/(R2^2+(S*X2)^2);//In N-m
disp(T,"Torque at 4% slip (in N-m) : ");
```

Scilab code Exa 1.35 `Stator Current and Power factor`

```
// Example 1.35

clear; clc; close;

format('v',7);
// Given data
V=400;//in volts
P=4;//no. of Poles
f=50;//in Hz
r1=0.15;//in ohm
x1=0.44;//in ohm
r2dash=0.12;//in ohm
x2dash=0.44;//in ohm
xm=30;//in ohm
S=4;//in %

//Calculations
S=S/100;//Slip
RLdash=r2dash*(1-S)/S;//in ohm
V1=V/sqrt(3);//in volt
I2rdash=V1/(r1+r2dash+RLdash+%i*(x1+x2dash));//in Ampere
I0=V1/(%i*xm);//in Ampere
I1=I0+I2rdash;//in Ampere
```

```
disp("Stator Current in Ampere : ");
disp("Magnitude is "+string(abs(I1))+" & angle in
    degree is "+string(atand(imag(I1),real(I1))));
cosfi=cosd(atand(imag(I1),real(I1)));//lagging power
     factor
disp(cosfi,"Power factor(lagging) : ");
```

Scilab code Exa 1.36 External Resistance

```
// Example 1.36

clear; clc; close;

// Given data
VL=440;//in volts
P=4;//no. of Poles
f=50;//in Hz
//Zleak=0.3+%i*5.5+0.25/S;//in ohm/phase
K=2.5;//Stator to rotor voltage ratio
T=150;//in N-m
N=1250;//in rpm

//Calculations
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//slip
Zleakage=1/3*(0.3+%i*5.5+0.25/S);//in ohm/phase
V1=VL/sqrt(3);//in volt
disp("I2rdash=V1/sqrt((0.1+Rx/S)^2+1.83^2) after
    adding additional resistance.");
disp("T=1/2/%pi/ns*3*I2rdash^2*Rx/S");
//R2x^2*T*S*2*%pi*ns/S^2+R2x*T*S*2*%pi*ns*0.2/S+T*S
    *2*%pi*ns*0.01+T*S*2*%pi*ns*1.83^2-3*(V1^2)*R2x
    =0;//equating
ns=Ns/60;//in rps
P=[T*S*2*%pi*ns/S^2 T*S*2*%pi*ns*0.2/S-3*(V1^2) T*S
```

```
*2*%pi*ns*0.01+T*S*2*%pi*ns*1.83^2];//polynomial for value of R2xdash
R2x=roots(P);//
R2x=R2x(1);//neglecting lower value
Rx_stator=R2x-0.083;//in ohm
format('v',5);
disp(Rx_stator,"External resistance referred to stator in ohm : ");
Rx_rotor=Rx_stator/K^2;//in ohm/phase
format('v',6);
disp(Rx_rotor,"External resistance rotor side in ohm/phase : ");
```

Scilab code Exa 1.37 Polar Slip and fields

```
// Example 1.37

clear; clc; close;

format('v',7);
// Given data
Nnl=1485;//in rpm
Nfl=1350;//in rpm
f=50;//in Hz

//Calculations
Ns=1500;//nearest syn speed to Nfl in rpm(Assumed)
//Formula : Ns=120*f/P
P=120*f/Ns;//no. of poles
disp("Part (i)");
disp(P,"No. of poles : ");
Snl=(Ns-Nnl)/Ns;//slip
disp("Part (ii)");
disp(Snl*100,"No load Slip in % : ");
Sfl=(Ns-Nfl)/Ns;//slip
```

```
disp(Sfl*100,"No load Slip in % : ");
fr_nl=f*Snl;//in Hz
fr_fl=f*Sfl;//in Hz
disp("Part (iii)");
disp(fr_nl,"No load frequency in Hz : ");
disp(fr_fl,"Full load frequency in Hz : ");
//Part (iv)
disp("On No Load : ");
N1=120*fr_nl/P;//speed of rotor field with respect to rotor conductor in rpm
disp(N1,"Speed of rotor field with respect to rotor conductor in rpm : ");
Rf_wrtS=1500;//in rpm
Rf_wrtSF=0;//in rpm
disp(Rf_wrtS,"Rotor field with respect to stator(rpm) : ");
disp(Rf_wrtSF,"Rotor field with respect to stator field(rpm) : ");
disp("On Full Load : ");
N2=120*fr_fl/P;//speed of rotor field with respect to rotor conductor in rpm
disp(N2,"Speed of rotor field with respect to rotor conductor in rpm : ");
Rf_wrtS=1500;//in rpm
Rf_wrtSF=0;//in rpm
disp(Rf_wrtS,"Rotor field with respect to stator(rpm) : ");
disp(Rf_wrtSF,"Rotor field with respect to stator field(rpm) : ");
//Answer of no load slip is wrong in the book.
```

Scilab code Exa 1.38 `Slip at Maximum Torque`

```
// Example 1.38

```

```
clear; clc; close;

format('v',7);
// Given data
VL=3.3;//in KV
P=20;//no of poles
f=50;//in Hz
R2=0.025;//in ohm/phase
X2=0.28;//in ohm/phase
N=294;//Full load speed in rpm

//Calculations
Sm=R2/X2;//Max Slip
disp(Sm*100,"Slip at max torque(in %) : ");
Ns=120*f/P;//in rpm
Sfl=(Ns-N)/Ns;//Full load slip
//Formula : T proportional to S*E2^2*R2/(R2^2+(S*X2)^2)
TmByTfl=Sm/(R2^2+(Sm*X2)^2)*((R2^2+(Sfl*X2)^2))/Sfl;//ratio
disp(TmByTfl,"Ratio of max to full load torqiue : ");
```

Scilab code Exa 1.39 Total Mechanical Power

```
// Example 1.39

clear; clc; close;

format('v',7);
// Given data
Pin=50;//in KW
StatorLoss=800;//in watts
f=50;//in Hz
fr=90;//cycles/min
```

```

//Calculations
fr=fr/60;//in Hz
S=fr/f;//slip
P2=Pin*1000-StatorLoss;//watts
//Formula : P2:Pc:Pm=1:S:1-S
Pm=P2*(1-S);//in watts
disp(Pm,"Total Mechanical power devloped in watts :
    ");
```

Scilab code Exa 1.40 Torque and power

```
// Example 1.40

clear; clc; close;

format('v',8);
// Given data
P=4;//no. of poles
VL=200;//in volt
f=50;//in Hz
R2=0.1;//in ohm/phase
X2=0.9;//in ohm/phase
S=4;//in %
K=0.67;//rotor to stator turns

//Calculations
S=S/100;//slip
E1ph=VL/sqrt(3);//in volt
E2ph=K*E1ph;//in volt
Ns=120*f/P;//in rpm
ns=Ns/60;//in rps
T=3/2/%pi/ns*S*E2ph^2*R2/(R2^2+(S*X2)^2);//in N-m
disp(T,"Total torque at 4% slip in N-m :");
Tm=3/2/%pi/ns*E2ph^2/2/X2;//in N-m
```

```
disp(Tm,"Maximum torque developed in N-m :");
Sm=R2/X2;//Max Slip
Nm=Ns*(1-Sm);//in rpm
disp(Nm,"Speed at max Torque in rpm : ");
Pmax=Tm*2*%pi*Nm/60;//in watts
disp(Pmax,"Maximum mechanical power in watts : ");
```

Scilab code Exa 1.41 Cu Loss and Efficiency

```
// Example 1.41

clear; clc; close;

format('v',8);
// Given data
P=6;//no. of poles
f=50;//in Hz
Tsh=150;//in N-m
fr=1.5;//in Hz
Tlost=10;//in N-m

//Calculations
S=fr/f;//slip
Ns=120*f/P;//in rpm
N=Ns*(1-S);//in rpm
RotationalLoss=Tlost*2*%pi*N/60;//in watts
Pout=Tsh*2*%pi*N/60;//in watts
Pm=Pout+RotationalLoss;//in watts
//Formula : P2:Pc:Pm=1:S:1-S
Pc=Pm*S/(1-S);//in watts
disp(Pc,"Rotor Copper Loss(Watts) : ");
P2=Pc/S;//in watts
disp(P2 ,"Input to the rotor(Watts) : ");
StatorLoss=700;//in watts(assumed)
Pin=P2+StatorLoss;//in watts]
```

```
Eff=Pout/Pin*100;//in %
disp(Eff,"Efficiency in % : ");
```

Scilab code Exa 1.42 Supply starting current

```
// Example 1.42

clear; clc; close;

format('v',6);
// Given data
Sfl=5;//in %
IscByIfl=6;//ratio

//Calculations
Sfl=Sfl/100;//slip
TstByTfl=1;//as Tfl=Tst
//Let X= tapping on transformer
X=sqrt(TstByTfl/(IscByIfl^2)/Sfl);//Tapping on
   transformer
disp(X,"Tapping on auto transformer : ");
IstByIfl=X^2*IscByIfl;//supply starting current to
   full load current
disp("The supply starting current is "+string(
   IstByIfl)+" times of full load current.");
```

Scilab code Exa 1.43 Ratio of Torque

```
// Example 1.43

clear; clc; close;

format('v',6);
```

```
// Given data
TmByTfl=2.5;//ratio
R2=0.4;//in ohm/phase
X2=4;//in ohm/phase

//Calculations
//Formula : Tm=K*E2^2/2/X2 and Tst=K*E2^2*R2/(R2^2+X2^2)
//E2=E2/sqrt(3);//for star delta starter
TstByTfl=(TmByTfl*2*X2)*R2/(R2^2+X2^2)/3;//calculated from above equations
disp(TstByTfl,"ratio of starting torque to full load torque is : ");
```

Scilab code Exa 1.44 Ratio of Torque

```
// Example 1.44

clear; clc; close;

format('v',6);
// Given data
Zouter=0.05+%i*0.10;//in ohm
Zinner=0.01+%i*0.60;//in ohm
S=3;//in %

//Calculations
R2o=real(Zouter);//in ohm
R2i=real(Zinner);//in ohm
X2o=imag(Zouter);//in ohm
X2i=imag(Zinner);//in ohm
S=S/100;//slip
//Formula : T=3/2/%pi/ns*(S*E2^2*R2/(R2^2+(S*X2)^2))
S=1;//at starting
TouterByTinner=R2o/R2i*(R2i^2+X2i^2)/(R2o^2+X2o^2);
```

```
    //
disp(TouterByTinner,"(i) Ratio of torque due to two
    cages at starting : ");
S=3/100;//Slip at running
TouterByTinner=R2o/R2i*(R2i^2+(S*X2i)^2)/(R2o^2+(S*
    X2o)^2);//
disp(TouterByTinner,"(ii) Ratio of torque due to two
     cages when running at 3% slip : ");
```

Scilab code Exa 1.45 Starting Torque

```
// Example 1.45

clear; clc; close;

format('v',4);
// Given data
Zi=0.6+%i*7;//in ohm
Zo=3.5+%i*1.5;//in ohm
Sfl=6;//in %

//Calculations
//At starting S=1
Ro=real(Zo);//in ohm
Ri=real(Zi);//in ohm
Xo=imag(Zo);//in ohm
Xi=imag(Zi);//in ohm
Zeq1=Zi*Zo/(Zi+Zo);//equivalent impedence in ohm
Req1=real(Zeq1);//in ohm
//I2=V/Zeq
//Tst=I2^2*R2;//in N-m

//During full load
S=Sfl/100;//slip
Zi=Ri/S+%i*Xi;//in ohm
```

```
Zo=Ro/S+%i*Xo;//in ohm
Zeq2=Zi*Zo/(Zi+Zo);//equivalent impedence in ohm
Req2=real(Zeq2);//in ohm
//I2=V/Zeq
//Tfl=I2^2*R2;//in N-m
TstByTfl=(1/abs(Zeq1)^2)/(1/abs(Zeq2)^2)*Req1/Req2;//ratio
disp("Starting torque is "+string(TstByTfl*100)+"% of full load torque.");
//Answer in the book is not accurate.
```

Scilab code Exa 1.46 Extra Resistance Required

```
// Example 1.46

clear; clc; close;

format('v',6);
// Given data
P=4;//no. of poles
f=50;//in Hz
R2=0.2;//in ohm per phase
X2=1;//in ohm per phase
Sf=4;//full load slip in %
N2=1260;//reduced speed in rpm

//Calculations
Sf=Sf/100;//full load slip
Ns=120*f/P;//in rpm
S2=(Ns-N2)/Ns;//new value of slip
//Let new resistance is R2dash
//Formula : T proportional to S*E2^2*R2/(R2^2+(S*X2)^2)
//T1=T2 as load is same
//R2dash^2*Sf*E2^2*R2-R2dash*[R2^2+(Sf*X2)^2]*(S2*E2
```

```
^2)+Sf*E2^2*R2*(S2*X2)^2=0
P=[Sf*R2 -[R2^2+(Sf*X2)^2]*(S2) Sf*R2*(S2*X2)^2];//polynomial for R2dash
R2dash=roots(P);
R2dash=R2dash(1);//discarding smaller value as R2dash cant be < R2
Rex=R2dash-R2
disp(Rex,"Extra resistance required in ohm per phase : ");
```

Scilab code Exa 1.47 `External Resistance required`

```
// Example 1.47

clear; clc; close;

format('v',6);
// Given data
P=4;//no. of poles
V2=415;//in volt
f=50;//in Hz
E2ByE1=1.75;//stator to rotor turn ratio
Z2=0.1+%i*0.9;//in ohm
I2=60;//in Ampere at start


X2=1;//in ohm per phase
Sf=4;//full load slip in %
N2=1260;//reduced speed in rpm

//Calculations
R2=real(Z2);//in ohm
X2=imag(Z2);//in ohm
E1ph=V2/sqrt(3);//in volt
E2ph=E1ph/E2ByE1;//in Volt
```

```
//Formula : I2=E2ph/sqrt(R2dash^2+X2^2)
R2dash=sqrt((E2ph/I2)^2-X2^2);//in ohm
Rex=R2dash-R2;//in ohm per phase
disp(Rex,"Extra resiatance required in ohm : ");
```

Scilab code Exa 1.48 Two speeds of motor

```
// Example 1.48

clear; clc; close;

format('v',6);
// Given data
P=16;//no. of poles
PM=4;//no. of poles of modulating function
n=1;//assumed
r=4;//assumed
f=50;//in Hz

//Calculations
check=n/r==1/3*(1-PM/P);
if check then
    disp("Equation is satisfied with -ve sign.");
    P2=P+PM;

end
check=n/r==1/3*(1+PM/P);
if check then
    disp("Equation is satisfied with +ve sign.")
    P2=P-PM;
end
Ns1=120*f/P;//in rpm
Ns2=120*f/P2;//in rpm
disp(Ns2,Ns1,"Two speeds(in rpm) are : ");
```

Scilab code Exa 1.49 `Various synchronous speeds`

```
// Example 1.49

clear; clc; close;

format('v',6);
// Given data
PA=4;//no. of poles
PB=6;//no. of poles
f=50;//in Hz

//Calculations
Ns=120*f/PA;//in rpm, A running alone
disp(Ns,"(1.) If A running alone, Speed in rpm is :
   ");
Ns=120*f/PB;//in rpm, B running alone
disp(Ns,"(2.) If B running alone, Speed in rpm is :
   ");
Ns=120*f/(PA+PB);//in rpm, Cumulative cascade
disp(Ns,"(3.) For Cumulative cascade, Speed in rpm
   is : ");
Ns=120*f/(PA-PB);//in rpm, Differential cascade
disp(Ns,"(4.) Differential cascade, Speed in rpm is
   : ");
```

Scilab code Exa 1.50 `Slip of machine`

```
// Example 1.50

clear; clc; close;

```

```
format('v',5);
// Given data
PA=4;//no. of poles
PB=6;//no. of poles
f=50;//in Hz
fr2=1;//in Hz

//Calculations
Nsc=120*f/(PA+PB);//synchronous speed of set in rpm
S=1;//Slip
N=Nsc-(S/f)*Nsc;//combined speed of set in rpm
disp(N,"Combibned spoeed of set in rpm : ");
NSA=120*f/PA;//in rpm
SA=(NSA-N)/NSA;//slip
disp(SA*100,"Slip of machines B in % : ");
fr1=SA*f;//in Hz
NSB=120*fr1/PB;//in rpm
SB=(NSB-N)/NSB;//slip
disp(SB*100,"Slip of machines B in % : ");
```

Scilab code Exa 1.51 External Resistance Required

```
// Example 1.51

clear; clc; close;

format('v',5);
// Given data
P=4;//no. of poles
f=50;//in Hz
R2=0.25;//in ohm per phase
X2=2;//in ohm per phase
N1=1455;//ion rpm
N2=N1*83/100;//in rpm

```

```
//Calculations
Ns=120*f/P;//synchronous speed in rpm
S1=(Ns-N1)/Ns;//Slip
S2=(Ns-N2)/Ns;//Slip at reduced speed
//Formula : T proportional to S*E2^2*R2/(R2^2+(S*X2)^2)
T1ByT2=1;//as T1=T2 & For T2: R2dash Rex+R2
//S1*R2*R2dash^2-R2dash(T1ByT2*S2*R2^2+T1ByT2*S2*(S1*X2)^2)+S1*R2*(S2*X2)^2=0
P=[S1*R2 -(T1ByT2*S2*R2^2+T1ByT2*S2*(S1*X2)^2) S1*R2*(S2*X2)^2];//Polynomial for R2dash
R2dash=roots(P);//in ohjm per phase
R2dash=R2dash(1);//neglecting lower value
Rex=R2dash-R2;//in ohm per phase
disp(Rex,"External resistance required in ohm per phase : ");
```

Scilab code Exa 1.52 Resistance in Series

```
// Example 1.52

clear; clc; close;

format('v',5);
// Given data
P=6;//no. of poles
f=50;//in Hz
Sf=3;//in %
R2=0.2;//in ohm per phase

//Calculations
Sf=Sf/100;//Slip
Ns=120*f/P;//in rpm
N1=Ns*(1-Sf);//in rpm
N2=N1*90/100;//in rpm
```

```
S2=(Ns-N2)/Ns;//new slip
//Formula : T=K*S*E2^2*R2/R2^2;//S*X2 is neglected
//Sf/R2=S2/(R2+r);  if Tfl=T20
r=(S2*R2)/Sf-R2;//Extra resistance required in ohm
disp(r,"Extra resistance necessery in series in ohm
    : ");
```

Scilab code Exa 1.53 Starting Torque

```
// Example 1.53

clear; clc; close;

format('v',6);
// Given data
IscByIfl=5;//ratio
Sf=5;//in %
K=50;//tapping in %

//Calculations
Sf=Sf/100;//Slip
//(i) Start delta
TstByTfl=1/3*IscByIfl^2*Sf;//ratio
disp("(i) Starting torque is "+string(TstByTfl*100)+
    "% of full load torque.");
//(ii) Auto Transformer having 50% tapping
K=K/100;//tapping
TstByTfl=K^2*IscByIfl^2*Sf;//ratio
disp("(ii) Starting torque is "+string(TstByTfl*100)
    +"% of full load torque.");
```

Scilab code Exa 1.54 Starting Torque and Current

```
// Example 1.54

clear; clc; close;

format('v',6);
// Given data
P=6;//no. of poles
f=50;//in Hz
Ifl=60;//in Ampere
N=940;//speed in rpm
Tfl=150;//in N-m
Isc=300;//in Ampere

//Calculations
Ns=120*f/P;//in rpm
Sf=(Ns-N)/Ns;//Slip full load
//Formula : Tst/Tfl=(Isc/Ifl)^2*Sf
Tst=(Isc/Ifl)^2*Sf*Tfl;//in N-m
disp(Tst,"Starting Torque in N-m : ");
//For Start delta
Tst=1/3*(Isc/Ifl)^2*Sf*Tfl;//in N-m
disp(Tst,"Starting Torque for star delta starter in
   N-m : ");
Isc=sqrt(3*Tst/Tfl/Sf)*Ifl;//in Ampere
disp(Isc,"Starting current for star delta starter in
    Ampere :  ");
```

Scilab code Exa 1.55 `Ratio of starting Torque`

```
// Example 1.55

clear; clc; close;

format('v',7);
// Given data
```

```
TmByTfl=2.2;//ratio
R2=0.5;//in ohm per phase
X2=5;//in ohm per phase
K=70;//tapping in %

//Calculations
//Formula :Tst proportional to E2^2*R2/(R2^2+X2^2)
//Formula :Tm proportional to E2^2/(2*X2)
//Formula :Tfl proportional to 1/4.4*E2^2/X2
TstByTfl=R2/(R2^2+X2^2)*TmByTfl*2*X2;//ratio for
    direct on line
disp(TstByTfl,"Ratio of starting torque to full load
     torque for direct on line starter : ");
TstByTfl=(1/sqrt(3))^2*R2/(R2^2+X2^2)*TmByTfl*2*X2;
    //ratio for star delta starting
disp(TstByTfl,"Ratio of starting torque to full load
     torque for star delta starter : ");
TstByTfl=(K/100)^2*R2/(R2^2+X2^2)*TmByTfl*2*X2;//
    ratio for auto transformer starting
disp(TstByTfl,"Ratio of starting torque to full load
     torque for auto transformer starter : ");
```

Scilab code Exa 1.56 Starting Torque to full Load Torque

```
// Example 1.56

clear; clc; close;

format('v',7);
// Given data
TmByTfl=3;//ratio
Sm=0.1;//slip at max Torque

//Calculations
TstByTfl_dol=2*Sm/(1+Sm^2)*TmByTfl;//ratio for D.O.L
```

```
starter
disp(TstByTfl_dol,"Ratio of starting torque to full load torque for D.O.L starter : ");
TstByTfl=1/3*TstByTfl_dol;//ratio for star delta starting
disp(TstByTfl,"Ratio of starting torque to full load torque for star delta starter : ");
//Anser of first part is not given in the book.
```

Scilab code Exa 1.57 Maximum possible KW

```
// Example 1.57

clear; clc; close;

format('v',7);
// Given data
VL=400;//in volt
Ist=1200;//in Ampere
Eff=0.85;//Efficiency
cosfi=0.8;//power factor
IstByIrated=5;//ratio

//Calculations
I2_rated=Ist/IstByIrated;//in Ampere
KWrating=sqrt(3)*VL*I2_rated*cosfi*Eff;//in KW
//To have star delta styarter tapping Xo=1/sqrt(3)
//Ist=X0^2*IstByIrated*IL
X0=1/sqrt(3);//tapping
IL=Ist/X0^2/IstByIrated;//in Ampere
KWmax=sqrt(3)*VL*IL*cosfi*Eff/1000;//in KW
disp(KWmax,"Maximum KW rating with star delta starter : ");
```

Scilab code Exa 1.58 `Starting Torque and Current`

```
// Example 1.58

clear; clc; close;

format('v',7);
// Given data
IscByIfl=3*180/100;//ratio
TstByTfl=0.35;//ratio
X=80/100;//tapping

//Calculations
//Formula : TstByTfl=1/3*(IscByIfl^2)*Sfl
Sfl=TstByTfl/IscByIfl^2*3;//slip at full load
IstByIsc=X^2;//ratio
IstByIfl=IstByIsc*IscByIfl;//ratio
disp("Starting current is "+string(IstByIfl)+" times
    of full load current.");
TstByTfl=X^2*IscByIfl^2*Sfl;//ratio
disp("Starting torque is "+string(TstByTfl*100)+"%
   of full load torque.");
```

Scilab code Exa 1.59 `Ratio of Torque`

```
// Example 1.59

clear; clc; close;

format('v',6);
// Given data
Zouter=0.05+%i*0.11;//in ohm
```

```
Zinner=0.015+%i*0.5;//in ohm

//Calculations
R2odash=real(Zouter);//in ohm
X2odash=imag(Zouter);//in ohm
R2idash=real(Zinner);//in ohm
X2idash=imag(Zinner);//in ohm
TouterByTinner=R2odash/(R2odash^2+X2odash^2)*(
    R2idash^2+X2idash^2)/R2idash;//ratio
disp(TouterByTinner,"Ratio of Torque due to two
    windinga : ");
```

Scilab code Exa 1.60 `Obtainable Speed`

```
// Example 1.60

clc;clear;close;

// Given data
PA=4;//no. of poles
PB=4;//no. of poles
f=50;//in Hz
V=440;//in volt

//calculations
//Independently with A
Ns=120*f/PA;//in rpm
disp(Ns,"Independently with A, Synchrpnous speed Ns
    in rpm is : ");
//Independently with B
Ns=120*f/PB;//in rpm
disp(Ns,"Independently with B, Synchrpnous speed Ns
    in rpm is : ");
//Running as cumulative cascaded
Ns=120*f/(PA+PB);//in rpm
```

```
disp(Ns,"Running as cumulative cascaded, Synchrpnous
    speed Ns in rpm is : ");
//Running as differentially cascaded
disp("Running as differentially cascaded,
   Synchrpnous speed Ns is undefined.");
```

Scilab code Exa 1.61 Starting Torque and Current

```
// Example  1.61

clc;clear;close;

// Given data
IscByIfl=3*180/100;//ratio
TstByTfl=35/100;//ratio
X=75;//tapping in %

//calculations
X=X/100;//tapping

//Star delta starting
//Formula : TstByTfl=1/3*IscByIfl*Sfl
Sfl=TstByTfl*3/IscByIfl^2;//slip at full load

//Auto transformer  starting
IstByIsc=X^2;//ratio
IstByIfl=X^2*IscByIfl;//ratio
disp("Starting current is "+string(IstByIfl*100)+"%
   of fulll load current.");
TstByTfl=X^2*IscByIfl^2*Sfl;//ratio
disp("Starting torque is "+string(TstByTfl*100)+"%
   of fulll load torque.");
//Answer of starting current in terms of full load
   curremt is not given in the book.
```

Scilab code Exa 1.62 Line current various starting

```
// Example 1.62

clc;clear;close;

// Given data
format('v',6)
VL=400;//in volt
f=50;//in Hz
I=100;//i Ampere

//calculations
//D.O.L starter
IL=I*sqrt(3);//in Ampere
disp(IL,"(i) The line current for direct on line starting in Ampere : ");
//In star delta starter
Vph=VL/sqrt(3);//in Volt
Iph=I/sqrt(3);//in Ampere
disp(Iph,"(ii) Starting phase current for star delta starting in Ampere : ");
disp(Iph,"(ii) Starting line current for star delta starting in Ampere : ");
//Auto transformer starter
K=70/100;//tapping of auto transformer
Vph=VL/sqrt(3);//in Volt
Vline=K*VL;//in volt
Ist_phase=Vline*I/VL;//in Ampere
disp(Ist_phase,"(iii) Starting phase current of motor in Ampere : ");
Ist_line=Ist_phase*sqrt(3);//in Ampere
disp(Ist_line,"(iii) Starting line current of motor in Ampere : ");
```

```
IsupplyLine=K*Ist_line;//in Ampere
disp(IsupplyLine,"(iii) Supply line current of motor
    in Ampere : ");
```

Scilab code Exa 1.63 Slip and No of Poles

```
// Example 1.63

clc;clear;close;

// Given data
format('v',6);
P=12;//no. of poles
Ns=500;//in rpm
Nr=1440;//in rpm

//calculations
f1=P*Ns/120;//in Hz
Nsm=1500;//in rpm (Assumed closed synchronous speed)
S=(Nsm-Nr)/Nsm;//slip
disp(S*100,"Slip of the motor in % : ");
Pm=120*f1/Nsm;//no. of poles of the motor
disp(Pm,"No. of poles of the motor : ");
```

Scilab code Exa 1.64 Slip and Speed

```
// Example 1.64

clc;clear;close;

// Given data
format('v',6);
P=4;//no. of poles
```

```
f1=50;//in Hz
f2=1.5;//in Hz

//calculations
S=f2/f1;//slip
disp(S*100,"Slip in % : ");
Ns=120*f1/P;//in rpm
N=(1-S)*Ns;//in rpm
disp(N,"Running speed of motor in rpm : ");
```

Scilab code Exa 1.65 Speed and Current

```
// Example 1.65

clc;clear;close;

// Given data
format('v',6);
P=6;//no. of poles
f1=50;//in Hz
S0=1;//in %
Sfl=3;//in %

//calculations
S0=S0/100;//slip
Sfl=Sfl/100;//slip
Ns=120*f1/P;//in rpm
disp(Ns,"(a) Synchronous speed in rpm : ");
N0=(1-S0)*Ns;//in rpm
disp(N0,"(b) No Load speed in rpm : ");
Nfl=(1-Sfl)*Ns;//in rpm
disp(Ns,"(c) Full load speed in rpm : ");
f2_st=f1*S0;//in Hz
disp(f2_st,"(d) Frequeny of rotor current at
    standstill in Hz : ");
```

```
f2_fl=f1*Sfl;//in Hz
disp(f2_fl,"(e) Frequeny of rotor current at full
    load in Hz : ");
//Answer of part (c) & part(d) is wrong. Calcultion
    mistake & slip is not divided by 100.
```

Scilab code Exa 1.66 Speed and Frequency

```
// Example 1.66

clc;clear;close;

// Given data
format('v',7);
P=4;//no. of poles
f1=50;//in Hz
S=4;//in %
R2=1;//in ohm/phase
X2=4;//in ohm/phase

//calculations
Ns=120*f1/P;//in rpm
S=S/100;//slip
//part (a)
N=(1-S)*Ns;//in rpm
disp(N,"(a) Speed of the motor in rpm : ");
//part (b)
f2=S*f1;//in Hz
disp(f2,"(b) Frequency of rotor emf in Hz  : ");
//part (i)
Z2=R2+%i*X2;//in ohm
cosfi=cosd(atand(imag(Z2),real(Z2)));//power factor
disp(cosfi,"(i) Power factor at standstill(lag) : ")
    ;
//part (ii)
```

```
N=1400;//speed in rpm (given for this part)
S1=(Ns-N)/Ns;//slip
Z2s1=R2+%i*S1*X2;//in ohm
cosfi=cosd(atand(imag(Z2s1),real(Z2s1)));//power
    factor at 1400 rpm speed
disp(cosfi,"(ii) Power factor at 1400 rpm(lag) : ");
```

Scilab code Exa 1.67 Rotor Current

```
// Example 1.67

clc;clear;close;

// Given data
format('v',6);
E=60;//in volt
Zrotor=0.8+%i*6;//rotor impedence in ohm/phase
Zstator=4+%i*3;//stator impedence in ohm/phase
S=5;//in %

//calculations
E2=E/sqrt(3);//emf induced/phase in volt
Ztotal=Zstator+Zrotor;//in ohm/phase
//Part (a)
I2=E2/Ztotal;//in Ampere
disp("Part(a) Magnitude is "+string(abs(I2))+" &
    angle in degree is "+string(atand(imag(I2),real(
    I2))));
//Part (b)
S=S/100;//slip
R2=real(Zrotor);//in ohm/phase
X2=imag(Zrotor);//in ohm/phase
I2s=S*E2/(R2+S*%i*X2);//in ampere
disp("Part(b) Magnitude is "+string(abs(I2s))+" &
    angle in degree is "+string(atand(imag(I2s),real(
```

```
    I2s))));
//Answer of part (b) is wrong in the book.
```

Scilab code Exa 1.68 Mechanical Power developed

```
// Example 1.68

clc;clear;close;

// Given data
format('v',7);
Pis=60;//in KW
phase=3;//no. of phase
S=3;//in %
StatorLaser=1;//in KW

//calculations
S=S/100;//slip
StatorOutput=Pis-StatorLaser;//in KW
RotorInput=StatorOutput;//in KW
RotorCuLoss=S*RotorInput;//in KW
RotorCuLoss_phase=S*RotorInput/phase;//in KW/phase
disp(RotorCuLoss_phase,"Rotor Copper loss per phase
    in KW : ");
MechPower=RotorInput-RotorCuLoss;//in KW
disp(MechPower,"Total mechanical lpower devloped in
    KW : ");
```

Scilab code Exa 1.69 Cu Loss Input and Efficciency

```
// Example 1.69

clc;clear;close;
```

```

// Given data
format('v',7);
P=6;//no. of poles
f1=50;//in Hz
f2=1.5;//in Hz
Zo=150;//useful Torque in N-m
FrictionLoss=10;//in N-m
Psc=700;//stator loss in watt

//calculations
Ns=120*f1/P;//in rpm
S=f2/f1;//slip
Nr=(1-S)*Ns;//in rpm
wr=2*%pi*Nr/60;//in rad/sec
Po=Zo*wr;//in watts
Pmd=(Zo+FrictionLoss)*wr;//in watts
//Part (a)
Prc=S/(1-S)*Pmd;//in watts
disp(Prc/1000,"(a) Rotor Copper Loss in KW : ");
//Part (b)
Pi=Pmd+Prc+Psc;//in watts
disp(Pi/1000,"(b) Input to the motor in KW : ");
//Part (c)
Eff=Po/Pi;//Effiiency
disp(Eff*100,"(d) Efficiency in % :  ");
```

Scilab code Exa 1.70 `Slip Speed Power Resistance`

```
// Example  1.70

clc;clear;close;

// Given data
format('v',6);
```

```
V=440;//in Volt
f=50;//in Hz
phase=3;//no. of phase
P=6;//no. of poles
Pin=80;//rotor input in KW
f1=50;//in Hz
f2=100;//in rotation/min
I=65;//rotor current in Ampere

//calculations
f2=f2/60;//in Hz
S=f2/f1;//slip
disp(S,"Slip(p.u) : ");
Ns=120*f/P;//in rpm
Nr=Ns*(1-S);//in rpm
disp(Nr,"Rotor speed in rpm : ");
RotorCuLoss=S*Pin*1000;//in Watts
Pmd=Pin*1000-RotorCuLoss;//Mechanical powre developed /in watts
Pmd=Pmd/746;//in HP
disp(Pmd,"Mechanical power developed in HP : ");
RotorCuLoss_phase=RotorCuLoss/phase;//in watts/phase
disp(RotorCuLoss_phase,"Rotor Coopper Loss per phase in watts : ");
R2=RotorCuLoss_phase/I^2;//in ohm
disp(R2,"Rotor resistance per phase in ohm : ");
```

Scilab code Exa 1.71 Resistance per phase

```
// Example 1.71

clc;clear;close;

// Given data
format('v',7);
```

```
f1=50;//in Hz
phase=3;//no. of phase
P=6;//no. of poles
Nr=960;//in rpm
GearCuLoss=250;//in watt
Power=25;//in HP
MechLoss=1000;//in watts
I2=35;//in Ampere

//calculations
Ns=f1*120/P;//in rpm
S=(Ns-Nr)/Ns;//slip
//Formula : RotorCuLoss=S/(1-S)*MechDevPower
//3*I2^2*R2+GearCuLoss=S/(1-S)*(Power*746+MechLoss)
R2=(S/(1-S)*(Power*746+MechLoss)-GearCuLoss)/3/I2^2;
    //in ohm
disp(R2,"Resistance per phase in ohm : ");
```

Scilab code Exa 1.72 `Slip I2R loss and current`

```
// Example 1.72

clc;clear;close;

// Given data
format('v',6);
V=500;//in Volt
f1=50;//in Hz
phase=3;//no. of phase
P=6;//no. of poles
Nr=995;//in rpm
Pm=20;//mech power in KW
StatorLoss=1500;//in watts
pf=0.87;//power facator

```

```
//calculations
Ns=f1*120/P;//in rpm
S=(Ns-Nr)/Ns;//slip
disp(S,"(a) Slip is : ");
Prc=S/(1-S)*Pm*1000;//in watts
disp(Prc,"(b) Rotor I^2*R Loss in watts : ");
RotorInput=Prc/S;//in watts
TotalInput=RotorInput+StatorLoss;//in watts
disp(TotalInput/1000,"(c) Total input in KW : ");
LineCurrent=TotalInput/sqrt(3)/V/pf;//in Ampere
disp(LineCurrent,"(d) Line current in Ampere : ")
fr=S*f1;//in Hz
disp(fr,"Rotor frequency in HZ : ");
```

Scilab code Exa 1.73 Rotor Mechanical Power

```
// Example 1.73

clc;clear;close;

// Given data
format('v',6);
StatorLoss=2;//in KW
StatorInput=90;//stator input in KW
S=4;//in %

//calculations
S=S/100;//slip
StatorOutput=StatorInput-StatorLoss;//in KW
Pri=StatorOutput;//rotor input in KW
Pcr=S*Pri;//in KW
disp(Pcr,"Rotor Copper Loss in KW : ");
Pm=Pri-Pcr;//in KW
disp(Pm,"Rotor mechanical power developed in KW : ")
    ;
```

Scilab code Exa 1.74 Current per phase in rotor

```
// Example 1.74

clc;clear;close;

// Given data
format('v',6);
emf=60;//in volt
R2=0.6;//in ohm
X2=4;//in ohm
Rrh=5;//in ohm
Xrh=2;//in ohm
S=4;//in %

//calculations
S=S/100;//slip
E2=emf/sqrt(3);//in volt
Rt=R2+Rrh;//in ohm
Xt=X2+Xrh;//in ohm
I2=E2/sqrt(Rt^2+Xt^2);//in Ampere
disp(I2,"(a) Current per phase in rotor in Ampere :
   ");
E2s=S*E2;//in volt
Z2s=sqrt(R2^2+(S*X2)^2);//in ohm
I2s=E2s/Z2s;//in Ampere
disp(I2s,"(b) Current per phase in rotor in Ampere :
   ");
```

Scilab code Exa 1.75 External resistance per phase

```
// Example 1.75

clc;clear;close;

// Given data
format('v',6);
R2=0.05;//in ohm
X2=0.1;//in ohm

//calculations
R2dash=X2;//for max Torque
r=R2dash-R2;//in ohm
disp(r,"External resistance per phase required in
    ohm : ");
```

Scilab code Exa 1.76 Maximum Torque and Speed

```
// Example 1.76

clc;clear;close;

// Given data
format('v',6);
P=6;//no. of poles
f=50;//in Hz
Sfl=4;//in %
Z2=0.01+%i*0.05;//in ohm

//calculations
S=Sfl/100;//slip
R2=real(Z2);//in ohm
X2=imag(Z2);//in ohm
Sm=R2/X2;//slip at max speed
Ns=120*f/P;//in rpm
Nm=(1-Sm)*Ns;//in rpm
```

```
TmaxByTfl=(S^2+Sm^2)/2/S/Sm;//ratio
disp("Maximum Torque is "+string(TmaxByTfl)+" times
    of full load torque.");
```

Scilab code Exa 1.77 Torque exerted by motor

```
// Example 1.76

clc;clear;close;

// Given data
format('v',6);
P=6;//no. of poles
f=50;//in Hz
Tmax=30;//in N-m
Nm=960;//in rpm
S=5;//in %
R2=0.6;//in ohm

//calculations
S=S/100;//slip
Ns=120*f/P;//in rpm
Sm=(Ns-Nm)/Ns;//slip at max speed
X2=R2/Sm;//in ohm
Tau_s=2*S*Sm/(S^2+Sm^2)*Tmax;//in N-m
disp(Tau_s,"Torque exerted by the motor in N-m : ");
```

Scilab code Exa 1.78 Resistance inserted in series

```
// Example 1.78

clc;clear;close;

```

```
// Given data
format('v',6);
P=4;//no. of poles
f=50;//in Hz
Tmax=110;//in N-m
Nm=1360;//in rpm
R2=0.25;//in ohm
TstByTmax=1/2;//ratio

//calculations
Ns=120*f/P;//in rpm
Sm=(Ns-Nm)/Ns;//slip at max speed
X2=R2/Sm;//in ohm
//Formula : Tmax=K*E2^2/2/X2 and Tst=K*E2^2*(R2+r)
    /((R2+r)^2+X2^2)
//TstByTmax*RT^2+TstByTmax*X2^2-RT*2*X2=0;
P=[TstByTmax -2*X2 X2^2*TstByTmax];//polynomial for
    RT
RT=roots(P);//in ohm
r=RT-R2;//in ohm
r=r(2);//leaving higher value as Tmax goes with S>1
    for this value
disp(r,"Resistance required in series in ohm :");
```

Scilab code Exa 1.79 Speed torque ratio and resistance

```
// Example 1.79

clc;clear;close;

// Given data
format('v',6);
P=16;//no. of poles
f=50;//in Hz
Z2=0.02+%i*0.15;//in ohm
```

```
Nr=360;//in rpm

//calculations
Ns=120*f/P;//in rpm
Sfl=(Ns-Nr)/Ns;//slip at full load
R2=real(Z2);//in ohm
X2=imag(Z2);//in ohm
Sm=R2/X2;//slip at max torque
Nm=(1-Sm)*Ns;//in rpm
disp(Nm,"(a) Speed at which max Torque occurs in rpm
    : ");
TmaxByTfl=(Sfl^2+Sm^2)/2/Sfl/Sm;//ratio
disp(TmaxByTfl,"Ratio of maximum to full load torque
    : ");
R2dash=X2;//for max Torque
r=R2dash-R2;//in ohm
disp(r,"(c) External resistance per phase required
   in ohm : ");
```

Scilab code Exa 1.80 Starting Torque

```
// Example 1.80

clc;clear;close;

// Given data
format('v',6);
P=6;//no. of poles
f=50;//in Hz
N=940;//in rpm
Output=7;//in KW
Nm=800;//in rpm
TotalLaser=840;//in watts

//calculations
```

```
Ns=120*f/P;//in rpm
S=(Ns-N)/Ns;//slip
Sm=(Ns-Nm)/Ns;//slip at max Torque
Pmd=Output*1000+TotalLaser;//in watts
//Formula : Pmd=2*%pi*N*Td/60
Tdfl=Pmd/2/%pi/N*60;//in N-m
Tst=Tdfl*(S^2+Sm^2)/S/(1+Sm^2);//in N-m
disp(Tst,"Starting tiorque in N-m : ");
```

Scilab code Exa 1.81 Torque and Power

```
// Example 1.81

clc;clear;close;

// Given data
format('v',6);
P=4;//no. of poles
f=50;//in Hz
VL=200;//in volt
R2=0.1;//in ohm
X2=0.9;//in ohm
Te2ByTe1=0.67;//ratio of rotor to stator turns
S=4;//in %

//calculations
S=S/100;//slip
Ns=120*f/P;//in rpm
E1=VL/sqrt(3);//in volt
E2=E1*Te2ByTe1;//in volt
Td=3*S*E2^2*R2/2/%pi/(Ns/60)/(R2^2+(S*X2)^2);//in N-
   m
disp(Td,"(a) Total torque at 4% slip in N-m : ");
Tmax=3*E2^2/2/%pi/(Ns/60)/(2*X2);//in N-m
disp(Tmax,"(b) Total torque at 4% slip in N-m : ");
```

```
Sm=R2/X2;//slip at max torque
Nm=(1-Sm)*Ns;//speed at Tmax in rpm
disp(Nm,"(c) Speed at maximum torque in rpm : ");
Pmd_max=2*%pi*Nm/60*Tmax;//in N-m
disp(Pmd_max,"(d) Maximum mechanical power in N-m : ");
```

Scilab code Exa 1.82 Slip and rotor current

```
// Example 1.82

clc;clear;close;

// Given data
format('v',7);
TstByTfl=1;//ratio
TmaxByTfl=2;//ratio

//calculations
TstByTmax=TstByTfl/TmaxByTfl;//ratio
//Formula : TstByTmax=2*Sm/(1+Sm^2)
//TstByTmax*Sm^2-2*Sm+TstByTmax=0
P=[TstByTmax -2 TstByTmax];//polynomial for Sm
Sm=roots(P);//slip at max torque
Sm=Sm(2);//neglecting the higher value
disp(Sm,"(a) Slip at which max torque occurs : ");
//Formula : TflByTmax=2*S*Sm/(S^2+Sm^2)
//S^2-TmaxByTfl*2*S*Sm+Sm^2=0
P=[1 -TmaxByTfl*2*Sm Sm^2];//polynomial for S
S=roots(P);//slip at max torque
//Sm=Sm(2);//neglecting the higher value
S=S(2);//neglecting the higher value
disp(S,"(b) Full load slip : ");
//I2stByI2fl^2=(Sm^2+S^2)/S^2/(1+Sm^2)
I2stByI2fl=sqrt((Sm^2+S^2)/S^2/(1+Sm^2));//ratio
```

```
disp(I2stByI2fl,"(c) Rotor current at starting ag
    full load current : ");
```

Scilab code Exa 1.83 `Starting Torque`

```
// Example  1.83

clc;clear;close;

// Given data
format('v',7);
Zst=25;//in N-m

//calculations
disp("Zst=K*R2/(R2^2+X2^2)");
//K=2*Zst*R2
KbyR2=2*Zst;//calculation
//(a) Tst=K*2*R2/((2*R2)^2+R2^2)
Tst=KbyR2*2/(2^2+1);//in N-m
disp(Tst,"(a) Starting torque in N-m ; ");
//(b) Tst=K/2*R2/((R2/2)^2+R2^2)
Tst=KbyR2/2/((1/2)^2+1);//in N-m
disp(Tst,"(b) Starting torque in N-m ; ");
```

Scilab code Exa 1.84 `Torque ratio and speed`

```
// Example  1.84

clc;clear;close;

// Given data
format('v',7);
P=4;//no. of poles
```

```
f=50;//in Hz
R2=0.4;//in ohm
X2=4;//in ohm

//calculations
Ns=120*f/P;//in rpm
Sm=R2/X2;//slip at max Torque
Nm=Ns*(1-Sm);//in rpm
disp(Nm,"Speed at Max Torque in N-m : ");
TmaxByTst=(1+Sm^2)/2/Sm;//ratio
disp(TmaxByTst,"Ratio of max Torque to starting Torque : ");
//After adding additional resistance
TstByTm=1/2;//given ratio
//TstByTm=2*X2*(R2+r)/((R2+r)^2+X2^2);//ratio
P=[TstByTm TstByTm*2*R2-2*X2 TstByTm*(R2^2+X2^2)-2*X2*R2];//polynomial for additional value of resistance
r=roots(P);//in ohm
r=r(2);//leaving higher value
disp(r,"Required resistance value in ohm ; ");
//Answer of resistance is wrong in the book.
```

Scilab code Exa 1.85 `Full load Slip and line Voltage`

```
// Example 1.85

clear; clc; close;

format('v',8);
// Given data
VL=440;//in volt
f=50;//in Hz
X2byR2=3;//ratio
TmByTfl=4;//ratio
```

```
//Calculations
Sm=1/X2byR2;//Maximum slip
//Formula : TmByTfl=(Sm^2+S^2)/(2*S*Sm)
P=[9 -24 1];//polynomial for value of S by avove
    equation
S=roots(P);
S=S(2);//discarding value greater than 1
disp(S,"(i) Full load slip : ");
TstByTfl=(Sm^2+S^2)/(S*(1+Sm^2));//ratio
disp(TstByTfl,"(ii) Ratio of starting torque to full
     load torque : ");
V1=VL/sqrt(3);//in volt
//Tst=Tfl : K*V11^2R2/(R2^2+X2^2)=R*V1*S*R2/(R2^2+(S
    *X2)^2)
V11=sqrt(S*V1^2*(1+X2byR2^2)/(1+(S*X2byR2)^2));//in
    volt
Linevoltage=V11*sqrt(3);//in volt
disp(Linevoltage,"(c) Line Voltage in Volt : ");
//Note : Answer of line voltage is wrong in the book
     due to calculation mistake.
```

Chapter 2

Single Phase Induction Motors

Scilab code Exa 2.1 `PF and Efficiency`

```
// Example 2.1

clear; clc; close;
format('v',6);

// Given data
Is=220;//in Ampere
//For no load
Vo=220;//in volt
Io=6;//in Ampere
wo=350;//in watt

//From locked rotor test
Vsc=125;//in volt
Isc=15;//in Ampere
Wsc=580;//in watt
R1=1.5*1.2;//in

//Calculations
Zeq=Vsc/Isc;//in
Req=Wsc/Isc^2;//in
```

```
Xeq=sqrt(Zeq^2-Req^2);//in
R1=1.5*1.2;//1.5 times more
R2=Req-R1;//in
//assume X1=X2; Xeq=X1+X2=2*X2
X2=Xeq/2;//in
X1=X2;//in
r2=R2/2;//in
x2=X2/2;//in

cos_fio=wo/(Vo*Io);//unitless
fi_o=acosd(cos_fio);//in degree
Io=Io*expm(%i*-fi_o*%pi/180);//in Ampere(polar form)
VAB=Vo-Io*[R1+r2/2+%i*(X1+X2/2)];//in volt
Xo=abs(VAB)/abs(Io);//in ohm
Xeq=2*Xo;//in ohm
S=5/100;//slip
Zf=Xo*expm(%i*%pi/2)*(r2/S+%i*X2/2)/(r2/S+%i*(X2/2+
    Xo));//in ohm
Z1=R1+%i*X1;//in ohm
Z2=6.4819+%i*3.416;//in ohm
Zeq=Z1+Z2+Zf;//in ohm
I1=Vo/Zeq;//in Ampere
PF=cos(atan(imag(I1),real(I1)));//lagging Power
    factor
disp(PF,"Power factor(lagging) : ");
Vf=I1*Zf;//in volt
I2f=Vf/(r2/S-%i*X2/2);//in Ampere
Zb=Zf;//in ohm
Vb=I1*Zb;//in Volt
I2b=Vb/(r2/(2-S)+%i*X2);//in Ampere
Pf=abs(I2f)^2*r2/S;//in watts
Pb=abs(I2b)^2*r2/(2-S);//in watts
Pm=(1-S)*(Pf-Pb);//in watts
Wo=350;//in watts
Pout=Pm-Wo;//in watts
Pin=Vo*abs(I1)*PF;//in watts
Eff=Pout/Pin*100;//in %
disp(Eff,"Efficiency in % : ");
```

```
//Answer in the book is wrong. Lots of mistake in
  the solution while calculating Zf.
```

Scilab code Exa 2.2 `Input Current PF and Efficiency`

```
// Example 2.2

clear; clc; close;
format('v',7);

// Given data
V1=110;//in volt
Z1=2+%i*3;//in ohm
Zeq_rotor=2+%i*3;//in ohm
Xo=50;//in ohm(Magnetising impedence)
Losses=25;//in watt(friction & voltage loss)
S=5/100;//slip

//Calculations
R1=real(Z1);//in
X1=imag(Z1);//in
R2=real(Zeq_rotor);//in
X2=imag(Zeq_rotor);//in
r2=R2/2;//in
x2=X2/2;//in
xo=Xo/2;//in ohm
Zf=%i*xo*(r2/S+%i*x2)/(r2/S+%i*(xo+x2));//in ohm
Zb=%i*xo*(r2/(2-S)+%i*x2)/(r2/(2-S)+%i*(xo+x2));//in
  ohm
Zeq=Z1+Zf+Zb;//in ohm
I1=V1/Zeq;//in Ampere
InputCurrent=abs(I1);//in Ampere
disp(InputCurrent,"Input current in Ampere : ");
PF=cos(atan(imag(I1),real(I1)));
disp(PF,"Power factor(lagging) : ");
```

```
Vf=I1*Zf;//in volt
I2f=Vf/(r2/S+%i*x2);//in Ampere
Vb=I1*Zb;//in Volt
I2b=Vb/(r2/(2-S)+%i*x2);//in Ampere
Pf=abs(I2f)^2*r2/S;//in watts
Pb=13.88;//in watts
Pm=(1-S)*(Pf-Pb);//in watts
Pout=Pm-Losses;//in watts
Pin=V1*abs(I1)*PF;//in watts
Eff=Pout/Pin*100;//in %
disp(Eff,"Efficiency in % : ");
```

Scilab code Exa 2.3 Value of Capacitor

```
// Example 2.3

clear; clc; close;
format('v',7);

// Given data
Pout=250;//in watt
V1=230;//in volt
f=50;//in Hz
Zm=4.5+%i*3.7;//in ohm
Za=9.5+%i*3.5;//in ohm

//Calculations
//Za=9.5+%i*3.5-%i*Xc;//in ohm(Xc assumed to be
    connected in auxiliary winding)
fi_a=90-atand(imag(Zm),real(Zm));//in degree
Ra=real(Za);//in ohm
Xa=imag(Za);//in ohm
X=tand(fi_a)*Ra;//in ohm
Xc=X+Xa;//in ohm
C=1/2/%pi/f/Xc;//in Farad
```

```
disp(C*10^6,"Value of capacitance in micro farad : "
  );
//Note : In the book, instead of Capacitance which
  is asked, Torque is calculated even not asked in
  question and not given the sufficient data to
  calculate it.
```

Scilab code Exa 2.4 Value of Capacitor

```
// Example 2.4

clear; clc; close;
format('v',7);

// Given data
f=50;//in Hz
Z1m=3+%i*2.7;//in ohm
Z1a=7+%i*3;//in ohm
alfa=90;//in degree

//Calculations
//Z1a=7+%i*3-%i*Xc;//in ohm(Xc assumed to be
  connected in auxiliary winding)
fi_a=90-atand(imag(Z1m),real(Z1m))
R1a=real(Z1a);//in ohm
X1a=imag(Z1a);//in ohm
X=tand(fi_a)*R1a;//in ohm
Xc=X+X1a;//in ohm
C=1/2/%pi/f/Xc;//in Farad
disp(C*10^6,"Value of capacitance in micro farad : "
  );
//Note : In the book, Torque is calculated even not
  asked in question and not given the sufficient
  data to calculate it.
```

Scilab code Exa 2.5 Value of Capacitance

```
// Example 2.5

clear; clc; close;
format('v',7);

// Given data
V1=230;//in volt
f=50;//in Hz
Vm=100;//in volt
Im=2;//in Ampere
Wm=40;//in watts
Va=80;//in volt
Ia=1;//in Ampere
Wa=50;//in watts

//Calculations
Z1em=Vm/Im;//in ohm
R1em=Wm/Im^2;//in ohm
X1em=sqrt(Z1em^2-R1em^2);//in ohm
R1m=R1em/2;//in ohm
X1m=X1em/2;//in ohm
fi_m=atand(X1m/R1m);//in degree

Z1ea=Va/Ia;//in ohm
R1ea=Wa/Ia^2;//in ohm
X1ea=sqrt(Z1ea^2-R1ea^2);//in ohm
Ra=R1ea-R1m;//in ohm
Xa=X1ea-X1m;//in ohm
fi_a=90-fi_m;//in degree
//after connecting capacitor
Xc=Xa-tand(-fi_a)*Ra
C=1/2/%pi/f/Xc;//in Farad
```

```
disp(C*10^6,"Value of capacitance in micro farad : "
    );
```

Chapter 3

Stepper Motors and Switched Reluctance Motors

Scilab code Exa 3.1.s `Step Angle`

```
// Sp_Example 3.1

clear; clc; close;

format('v',7);
// Given data
Ns=12;//poles
q=3;//no. of phase
Nr=8;//poles
speed=6000;//speed in rpm

//Calculations
Beta=360/q/Nr;//in degree
disp(Beta,"Step Angle in degree : ");
fc=Nr*speed*2*%pi/2/%pi/60;//in Hz
disp(fc,"Commutation frequency at each phase in Hz :
    ");
```

Scilab code Exa 3.1 `Time taken and Stored Inductive energy`

```
// Example 3.1

clear; clc; close;

format('v',8);
// Given data
Lm=30;//in mH
Iph=3;//in Ampere
Rm=15;//in Ohm

//Calculations
tau_ed=Lm/Rm;//in ms
tdash=1/2*tau_ed;//in ms
disp(tdash,"(i) Time taken by the phase current to
    decay to zero in ms : ");
Energy=1/4*Lm*Iph^2;//in mW
disp(Energy,"(ii) Energy returned to supply in mW :
    ");
```

Scilab code Exa 3.2.s `Step Angle and Commutation Frequency`

```
// Sp_Example 3.2

clear; clc; close;

format('v',7);
// Given data
Ns=10;//poles
q=5;//no. of phase
Nr=4;//poles
```

```
w=600;//speed in rpm

//Calculations
Beta=360/q/Nr;//in degree
disp(Beta,"Step Angle in degree : ");
fc=Nr*w/60;//in Hz
disp(fc,"Commutation frequency at each phase in Hz :
    ");
//Note : Answer is wrong in the book.
```

Scilab code Exa 3.2 Step Angle

```
// Example 3.2

clear; clc; close;

format('v',8);
// Given data
n=4;//no. of phase
Ns=12;//stator teeth
Nr=3;//rotor teeth

//Calculations
Beta=360/n/Nr;//in degree
disp(Beta,"Step Angle in degree : ");
```

Scilab code Exa 3.3.s Instantaneous and average Torque

```
// Sp_Example 3.3

clear; clc; close;

format('v',6);
```

```
// Given data

Ns=6;//poles
Nr=4;//poles
Beta_s=30;//in degree
Beta_r=32;//in degree
La=10.7;//in mH
LU=1.5;//in mH
i=7;//in A
q=3;//phase

//Calculations
thetaK=2*180/4-(Beta_r+Beta_s)/2;//in degree
theta1=thetaK;//in degree
thetaY=2*180/2-(Beta_r-Beta_s)/2;//in degree
theta2=thetaY;//in degree
dTheta=theta2-theta1;//in degree
dL=La-LU;//in mH
T=i^2/2*dL/dTheta;//in N-m
lambda_a=La*i*10^-3;//in m
lambda_u=LU*i*10^-3;//in m
Wm=(lambda_a-lambda_u)/2*i;//in joules
//Formula : Power transfered = Energy 1 sec
//Pm=2*%pi*N*T/60=Wm*Nr*q*N/60
T=Wm*Nr*q/2/%pi;//in N-m
disp(T,"Averagge torque in N-m : ");
```

Scilab code Exa 3.3 Step Angle

```
// Example 3.3

clear; clc; close;

format('v',6);
// Given data
```

```
MainPoles=10;//no. of main poles
teeth=7;//no. of teeth/pole
Nr=60;//rotor teeth

//Calculations
Ns=MainPoles*teeth;//stator teeth
Beta=(Ns-Nr)*360/Ns/Nr;//in degree
disp(Beta,"Step Angle in degree : ");
```

Scilab code Exa 3.4.s `Energy Conversion and Avg Tourque`

```
// Sp_Example 3.4

clear; clc; close;

format('v',6);
// Given data
Nr=4;//poles
La=10.7;//in mH
Lu=1.5;//in mH
i=7;//in A
q=3;//phase

//Calculations
lambda_a=La*10^-3*i;//in Wb/T
lambda_u=lambda_a;//in Wb/T
i2=lambda_u/Lu/10^-3;//in Ampere
Wm=(i2-i)*lambda_u/2;//in Jooules
disp(Wm,"Energy conversion per stroke in Joules : ")
    ;
T=Wm*q*Nr/2/%pi;//in N-m
disp(T,"Average Tourque in N-m : ");
```

Scilab code Exa 3.4 Resolution Steps and Shaft speed

```
// Example 3.4

clear; clc; close;

format('v',6);
// Given data
Beta=3;//in degree
Revolution=25;//no. of revolutions
f=3600;//stepping frequency in pps

//Calculations
Resolution=360/Beta;//in step/res
disp(Resolution,"(a) Resolution(step/res) : ");
steps=Resolution*Revolution;//no. of steps
disp(steps,"(b) No. of steps required : ");
speed=Beta*f/360;//in nps
disp(speed,"(c) Shaft speed in nps : ");
```

Scilab code Exa 3.5 Resolution Speed and Pulses

```
// Example 3.5

clear; clc; close;

format('v',6);
// Given data
Beta=1.8;//in degree
Revolution=25;//no. of revolutions
f=4000;//stepping frequency in pps
theta=54;//required shaft rotation in degree

//Calculations
Resolution=360/Beta;//in step/res
```

```
disp(Resolution,"(i) Resolution(step/res) : ");
speed=Beta*f/360;//in rps
disp(speed,"(ii) Motor speed in rps : ");
pulses=theta/Beta;//pulses
disp(pulses,"(iii) No. of pulses required to rotate
    the shaft through 54 degree : ");
```

Scilab code Exa 3.6 Resolution

```
// Example 3.6

clear; clc; close;

format('v',6);
// Given data
Ns=8;//stator teeth
Nr=6;//rotor teeth

//Calculations
Beta=(Ns-Nr)/Ns/Nr*360;//in degree
disp(Beta,"Step angle(degree) : ");
Resolution=360/Beta;//steps/revolution
disp(Resolution,"Resolution(steps/revolution) : ");
```

Scilab code Exa 3.7 Rotor and Stator Poles

```
// Example 3.7

clear; clc; close;

format('v',6);
// Given data
Beta=15;//in degree
```

```
m=3;//no. of phase(1-Beta*Nr/360)

//Calculations
//Formula : Beta=360/m/Nr
Nr=360/m/Beta;//no. of rotor teeth
disp(Nr,"No. of rotor teeth ; ");
//Formula : Beta=(Ns~Nr)/Ns/Nr*360;//in degree
//When Ns>Nr
Ns=Nr/(1-Beta*Nr/360);//no. of stator teeth
disp(Ns,"When Ns>Nr, No. of stator teeth : ");
//When Nr>Ns
Ns=Nr/(1+Beta*Nr/360)
disp(Ns,"When Nr>Ns, No. of stator teeth : ");
```

Scilab code Exa 3.8 Rotor and Stator Teeth

```
// Example 3.8

clear; clc; close;

format('v',6);
// Given data
m=4;//phases
Beta=1.5;//in degree

//Calculations
//Formula : Beta=360/m/Nr
Nr=360/m/Beta;//no. of rotor teeth
disp(Nr,"No. of rotor teeth ; ");
Ns=Nr;//no. of stator teeth
disp(Ns,"In multi stack motor, Stator teeth = rotor
    teeth = ");
```

Scilab code Exa 3.9 `Pulse Rate`

```
// Example 3.9

clear; clc; close;

format('v',6);
// Given data
Speed=2400;//in rpm
Resolution=200;//steps/res

//Calculations
n=Speed/60;//in rps
Beta=360/Resolution;//in degree
//Formula : n=Beta*f/360;
f=n*360/Beta;//in pps
disp(f,"Required pulse rate in pps : ");
```

Scilab code Exa 3.10 `Resolution and No of steps`

```
// Example 3.10

clear; clc; close;

format('v',6);
// Given data
Resolution=500;//steps/res
theta=72;//rotator turn angle in degree
//Calculations
Hmod_Res=Resolution*2;//half step mode resolution in
    steps/res
disp(Hmod_Res,"Half step mode resolution in steps/
    res : ");
Beta=360/Hmod_Res;//in degree
steps=theta/Beta;//in steps
```

```
disp(steps,"No. of steps required : ");
```

Scilab code Exa 3.11 No loaded into encoder

```
// Example 3.11

clear; clc; close;

format('v',6);
// Given data
Beta=1.8;//in dcegree
revolution=10;//no. of revolution
//Calculations
resolution=360/Beta;//in  steps/rev
steps=resolution*revolution;//no. of steps in 10
    evolution
disp("No. of steps = "+string(steps)+" should be
    encoded.");
```

Scilab code Exa 3.12 Motor Torque

```
// Example 3.12

clear; clc; close;

format('v',6);
// Given data
J=10^-4;//in Kgm^2;
w1=200;//in rad/sec
w2=300;//in rad/sec
delf=0.2;//in sec
Tf=0.06;//in N-m

```

```
//Calculations
dwBYdf=(w2-w1)/delf;//
Tm=J*dwBYdf+Tf;//in N-m
disp(Tm,"Motor Torque in N-m : ");
```

Scilab code Exa 3.13 Motor Torque

```
// Example 3.13

clear; clc; close;

format('v',7);
// Given data
J=3*10^-4;//in Kgm^2;
f1=1000;//in Hz
f2=2000;//in Hz
delt=100;//in ms
Tf=0.05;//in N-m
Qs=1.8;//in degree

//Calculations
delt=100*10^-3;//in sec
Qs=Qs*%pi/180;//in radian
w1=Qs*f1;//in rad/sec
w2=Qs*f2;//in rad/sec
dwBYdt=(w2-w1)/delt;//
Tm=J*dwBYdt+Tf;//in N-m
disp(Tm,"Motor Torque in N-m : ");
```

Scilab code Exa 3.14 Maximum Acceleration

```
// Example 3.14

```

```
clear; clc; close;

format('v',7);
// Given data
J=4*10^-4;//in Kgm^2;
Tm=0.3;//in N-m
Qs=3;//in degree

//Calculations
Qs=Qs*%pi/180;//in radian
//Formula : Tm=J*Qs*dfBYdt;//in N-m
dfBYdt=Tm/J/Qs;//in step/sec^2
disp(dfBYdt,"Maximum acceleration in steps/sec^2 : ");
```

Chapter 4

Permanent Magnet Generators

Scilab code Exa 4.1 No Load Speed

```
// Example 4.1

clear; clc; close;
format('v',7);

// Given data
kf=0.12; //  in Nm/A
V=48;//in volt

//Calculations
omega_mo=V/kf//in radian/sec
No=omega_mo*60/(2*%pi)//in rpm
disp(floor(No),"No load speed in rpm = ");
```

Scilab code Exa 4.2 No Load Speed

```
// Example 4.2

```

```
clear; clc; close;
format('v',7);

// Given data
Tst=1; //  in N-m
Ist=5;//in Ampere
V=28;//in volt

//Calculations
kf=Tst/Ist;//in Nm/A
omega_m=V/kf//in radian/sec
No=omega_m*60/(2*%pi)//in rpm
disp(No,"No load speed in rpm = ");
```

Scilab code Exa 4.3 Speed of Motor

```
// Example 4.3

clear; clc; close;
format('v',6);

// Given data
Ra=0.8;//in
Vdd=2;//in volt
V=28;//in volt
T1=0.3; //  in N-m
Tst=1; //  in N-m
Ist=5;//in Ampere

//Calculations
//We know : Tst = fi_1*Ist  and T1 = IL*fi_2
//Deviding these two eqn we have
IL=(T1/Tst)*Ist/0.8;//in Ampere
Ebo=V;//in volt
NLbyNo=(V-IL*Ra-Vdd)/(0.8*Ebo);// temporary
```

```
calculation for NL
No=1337;//in rpm
NL=NLbyNo*No;//in rpm
disp(NL,"Speed of motor in rpm =");
```

Scilab code Exa 4.4 No Load Speed

```
// Example 4.4

clear; clc; close;
format('v',7);

// Given data
ke=0.12;//in Nm/A
V=48;//in volt
Rph=0.15;//in
Vdd=2;//in volt

//Calculations
omega_mo=V/ke//in radian/sec
No=omega_mo*60/(2*%pi)//in rpm
disp(No,"No load speed in rpm = ");

Ist=(V-Vdd)/(2*Rph);//in Ampere
Tst=ke*Ist; //  in N-m
disp(Tst,"Starting Torque  in N-m = ");
//Note : answer is wrong in the book.
```

Scilab code Exa 4.5 Speed of Motor

```
// Example 4.5

clear; clc; close;
```

```
format('v',7);

// Given data
Vs=120;//in volt
V=60;//in volt
Ra=2.5;//in
T=0.5; //  in N-m
N=6000//in rpm

//Calculations

omega_mo=2*%pi*N/60//in radian/sec
ke=Vs/omega_mo;//in Nm/A
Ia=T/ke;//in Ampere
E=V-Ia*Ra;//in Volt
omega_m=E/ke//in radian/sec
N=omega_m/(2*%pi/60);//in rpm
disp(N,"Speed in rpm = ");
//Note : answer is wrong in the book because
   calculation is not accurate. .
```

Scilab code Exa 4.6 `Calculate Torque`

```
// Example 4.6

clear; clc; close;
format('v',9);

// Given data
lm=6*10^-3;//magnet length in m
g=2*10^-3;//in m
Tph=200;//turns
Br=0.3;//in T
l=50*10^-3;//in m
n=25*10^-3;//in m
```

```
I=10*10^-3;//in A
N=200;//turns
mo=4*%pi*10^-7;//permittivity
//Calculations
Am=(2/3)*%pi*[n-g-lm/2]*l;//in m^2
Ag=[(2/3)*%pi*(n-g/2)+2*g]*(l+2*g);//in m^2
Cfi=Am/Ag;//unitless
//For normal BLDG motor, HC=606 KA/M
HC=606;//in  KA/M
Hm=N*I/l;//KA/M
Bm=Br*[1-Hm/HC];//in T
Mrec=(Br-Bm)*10^-3/(4*%pi*10^-7*40);
Pmo=mo*Mrec*Am/lm;//in m-Wb/AT
Pmo=Pmo*10^-3;//in Wb/AT
Kc=1.05;//given constant
g_dash=Kc*g;//in m
Rg=g_dash/mo/Am;
Bg=Cfi*Br/(1+Pmo*Rg);//in T
Torque=2*Tph*Bg*l*n*I;//in N-m
disp(Torque,"Torque per phase in N-m : ");
```

Scilab code Exa 4.7 Frequency Phase and Line EMF

```
// Example 4.7

clear; clc; close;
format('v',6);

// Given data
P=16;//no.of poles
slots=144;//no. of slotes
conductors=10;//per slot
fi=0.03;//in mb/pole
N=375//in rpm

```

```
//Calculations
f=P*N/120;//in Hz
disp(f,"Frequency in Hz = ");
kc=1;//for full pitcheed coil
n=slots/P;//slots per pole
Beta=180/n;//in degree
m=n/3;//slots per pole per phase
kd=sind(3*Beta/2)/[m*sind(Beta/2)];//Distribution
    factor
Z=conductors*slots;//total no. of conductors
Zph=Z/3;// no. of armature per phase conductions
Tph=Zph/2;//turns/ph
Eph=4.44*kc*kd*f*fi*Tph;//in volts
disp(Eph,"Phase Voltage in volts = ");
VL=sqrt(3)*Eph;//in volt
disp(VL,"Line Voltage in volts = ");
```

Scilab code Exa 4.8 Open Circuit Phase EMF

```
// Example 4.8

clear; clc; close;
format('v',6);

// Given data
P=4;//no.of poles
phase=3;//no. of phase
slots=36;//no. of stator slotes
turns=20;//turns per coil
conductors=10;//per slot
fi_m=1.8;//in m wb
N=3000//in rpm

//Calculations
f=P*N/120;//in Hz
```

```
Tph=turns*phase*P;//no. of turns per phase
m=slots/(phase*P);//slots per pole per phase
n=slots/P;//slots per pole
Beta=180/n;//in degree
kd1=sind(3*Beta/2)/[m*sind(Beta/2)];//Distribution
   factor
alfa=2*Beta;//in degree(Short Pitched by 2slots)
kp1=cosd(alfa/2);//unitless
ks1=1;//coefficient
kn1=kd1*kp1*ks1;//winding factor
Eq=4.44*f*fi_m*10^-3*kn1*Tph;//in volts
disp(Eq,"Open Circuit Phase emf in volts = ");
```