Scilab Textbook Companion for Electric Machines by D. P. Kothari And I. J. Nagrath[1]

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Book Description

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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 2

Magnetic circuits and Induction

Scilab code Exa 2.1 calculating exciting current and corresponding flux linkages

```
// calculating exciting current and corresponding
   flux linkages

clc;
U_o=4*%pi*10^-7;
U_r=6000;
l_g=0.0006;
l_c=.40;
A_c=.04*.04;
B_c=1.2;
N=600;
function [i]=current(B_g)
    i=(1/(U_o*N))*(((B_c*l_c)/U_r)+(B_g*l_g));
endfunction
disp(current(B_c),'neglecting fringing,current(A)=')
   ;

    phi=B_c*A_c;
disp(phi,'flux(Wb)=');

```

```
function [lmda]=flux_linkage(phi)
    lmda=N*phi;
endfunction
disp(flux_linkage(phi),'flux linkages(Wb-turns)=');

A_g=(.04+l_g)^2;
B_g=phi/A_g;

disp(current(B_g),'fringing taken into account,
   current(A)=');
```

Scilab code Exa 2.2 Calculation of current reqd to produce flux in the given magnetic circuit

```
//Calculation of current reqd to produce flux in the
    given magnetic circuit.

clc;
U_o=4*%pi*10^-7;
U_r=4000;
N=600;
//l_c=.30;
//l_g=.001;
dia=.02;
phi=.5*10^-3;          //flux
A=(%pi/4)*dia^2;
function [i]=current(l_c,l_g)
    R=((l_c/U_r)+l_g)/(U_o*A);
    i=(phi*R)/N;
endfunction
disp(current(.30,0),'no air gap current(A)');
disp(current(.30,.001),'with air gap current(A)');

//B-H data
//H in AT/m    2500    3000    3500    4000
```

```
//B in T          1.55      1.59      1.6      1.615

B_g=phi/A;
disp(B_g,'B(T)');

H_g=B_g/U_o;

function [AT]=AT(H,l)
    AT=H*l;
endfunction
AT_g=AT(H_g,.001);
disp(ceil(AT_g),'AT_g');

H_c=3000;
AT_c=AT(H_c,.30);
disp(AT_c,'AT_c');

i=(AT_g+AT_c)/N;
disp(i,'from magnetisation data, current(A)');
```

Scilab code Exa 2.3 Determination of mmf of the exciting coil

```
// Determination of mmf of the exciting coil

clc;
U_o=4*%pi*10^-7;
A1=.0001;
A2=.0002;
l1=.025*10^-2;
l2=.02*10^-2;
phi=.75*10^-3;
function [Re]=reluctance(l,U_r,A)
    Re=l/(U_o*U_r*A);
endfunction

```

```
function [Ni]=mmf(R1,R2,R3)
    Ni=phi*(R3+((R1*R2)/(R1+R2)));
endfunction
R_g1=reluctance(l1,1,A1);
R_g2=reluctance(l2,1,A1);
R_g3=reluctance(l2,1,A2);
disp(mmf(R_g1,R_g2,R_g3),'when U_r=1,mmf(AT)');
L1=l1*2*10^3;
L2=l2*10^3;
R_c1=reluctance(L1,5000,A1);
R_c2=reluctance(L1,5000,A1);
R_c3=reluctance(L2,5000,A2);
disp(mmf(R_c1+R_g1,R_c2+R_g2,R_c3+R_g3),'when U_r
    =5000,mmf(AT)');
```

Scilab code Exa 2.4 Exciting current calculation needed to setup reqd flux

```
// Exciting current calculation needed to setup reqd
    flux

clc;
U_o=4*%pi*10^-7;
A1=800*10^-6;
A2=600*10^-6;
l1=1*10^-3;              //air gap length
l2=160*10^-3;            //length of central limb
l3=400*10^-3;            //length of side limb
phi=.8*10^-3;
N=500;
function [B]=fd(A)
   B=phi/A;
endfunction

function [F]=mmf(l,B)
    F=l/B;
```

```
endfunction
//air gap
B_g=fd(A1);
F_g=mmf(l1,B_g)/U_o;disp(F_g,'F_g(AT)');
//central limb
B_c=B_g;
F_c=mmf(l2,B_c)/10^-3;disp(F_c,'F_c(AT)');
//outer limb                flux is divided into
   half
B_o=fd(A2)/2;
F_o=mmf(l3,B_o)/(4*10^-3);disp(F_o,'F_o(AT)');
i=(F_g+F_c+F_o)/N;              //    total mmf/no of
   turns
disp(i,'exciting current(A)');
```

Scilab code Exa 2.5 determination of excitation coil mmf

```
// determination of excitation coil mmf
clc;
U_o=4*%pi*10^-7;
A1=25*10^-4;
A2=12.5*10^-4;
A3=25*10^-4;
l1=.5;            //length of side limb(ab+cd)
l2=.2;          //length of central limb(ad)
l3=.5;            //length of side limb(dea)
l4=.25*10^-3;          //length of air gap
phi=.75*10^-3;
N=500;
function [B]=fd(A)
    B=phi/A;
    endfunction
function [F]=flux(B,l)
    F=B*l/(U_o);
    endfunction
```

```
function [f]=fl(H,l)
f=H*l;
endfunction
B_abcd=fd(A1);
F_bc=flux(B_abcd,l4);
disp(B_abcd,'B_abcd(T)');
H_ab=200;                              //for cast iron for B=0.3
F_abcd=fl(H_ab,l1);
F_ad=F_abcd+F_bc;
H_ad=F_ad/l2;
disp(H_ad,'H_ad(AT/m)');
B_ad=1.04                              //for cast iron for H=800
phi_ad=B_ad*A2;
phi_dea=phi+phi_ad;
B_dea=phi_dea/A3;
H_dea=500                               //for cast iron for B=.82
F_dea=H_dea*l3;
F=F_dea+F_ad;
disp(F,'reqd mmf(AT)');
```

Scilab code Exa 2.7 determination of self and mutual inductance bw 2 coils

```
//determination of self and mutual inductance b/w 2 coils

clc;
U_o=4*%pi*10^-7;
U_r=1600;
A1=4*10^-4;
A2=4*10^-4;
A0=2*10^-4;
```

```
N1=500;
N2=1000;

l1=.01*((6+0.5+1)*2+(4+2));
l2=.01*((3+0.5+1)*2+(4+2));
l0=.01*(4+2);
function [R]=reluc(l,A)
    R=l/(U_o*U_r*A);
endfunction
R1=reluc(l1,A1);
R2=reluc(l2,A2);
R0=reluc(l0,A0);

function [re]=re(r0,r1,r2)
    re=r0+((r1*r2)/(r1+r2));
endfunction

disp('coil 1 excited with 1A');
R_1=re(R1,R0,R2);
phi1=N1/R_1;
phi2=phi1*R0/(R0+R2);
L11=N1*phi1;disp(L11,'self inductance(H)');
M21=N2*phi2;disp(M21,'mutual inductance(H)');
disp('coil 2 excited with 1A');
R_2=re(R2,R0,R1);
phi2=N2/R_2;
L22=N2*phi2;disp(L22,'self inductance(H)');
M12=M21;disp(M12,'mutual inductance(H)');
```

Scilab code Exa 2.8 determination of Rc Rg L Wf

```
//determination of R_c,R_g,L,W_f

clc;
U_o=4*%pi*10^-7;
```

```
U_r=6000;
l_g=0.0006;
l_c=.40;
A_c=.04*.04;
B_c=1.2;
N=600;
function [i]=current(B_g)
    i=(1/(U_o*N))*(((B_c*l_c)/U_r)+(B_g*l_g));
endfunction
disp(current(B_c),'neglecting fringing ,current(A)=')
    ;

    phi=B_c*A_c;
disp(phi,'flux(Wb)=');

function [lmda]=flux_linkage(phi)
    lmda=N*phi;
endfunction
disp(flux_linkage(phi),'flux linkages(Wb-turns)=');

function [R]=reluc(l,U,A)
    R=l/(U_o*U*A);
endfunction
R_c=reluc(l_c,U_r,A_c);disp(R_c,'R_c=');
R_g=reluc(l_g,1,A_c);disp(R_g,'R_g=');

L=N^2/(R_c+R_g);
disp(L,'coil inductance(H)');

W_f=(N*phi)^2/(2*L);
disp(W_f,'energy stored in the magnetic field(J)');
```

Scilab code Exa 2.9 calculation of hysterisis and eddy current losses

```
// calculation of hysterisis and eddy current losses
```

```
clc;
P1=1500;
f1=50;
P2=3000;
f2=75;
A=[1 50;1 75];                //P/f=A+B*f
B=[30;40];
v=A\B;

disp('at 50Hz');
P_h=v(1)*f1;disp(P_h,'hysterisis loss(W)');
P_e=v(2)*f1^2;disp(P_e,'eddy current loss(W)');

disp('at 75Hz');
P_h=v(1)*f2;disp(P_h,'hysterisis loss(W)');
P_e=v(2)*f2^2;disp(P_e,'eddy current loss(W)');
```

Chapter 3

Transformers

Scilab code Exa 3.1 To determine no load power factor core loss current and magnetising current and no load ckt parameters of transformer

```
// To determine no load power factor ,core loss
   current and magnetising current
//  and no load ckt parameters of transformer

clc;
Pi=50;
V1=230;
Io=2;
pf=Pi/(V1*Io);disp(pf,'no load power factor');
Im=Io*sind(acosd(pf));disp(Im,'magnetising current(A
   )');
Ii=Io*pf;disp(Ii,'core loss current(A)');
Gi=Pi/V1^2;disp(Gi,'Gi(mho)');
Bm=Im/V1;disp(Bm,'Bm(mho)');
```

Scilab code Exa 3.2 To calculate no load current and its pf and no load power drawn from mains

```
// To calculate no load current and its pf and no
   load power drawn from mains

clc;
E=200;
f=50;
N1=150;          // no of turns
b1=.1;
b2=.05;
phi_max=E/(4.44*f*N1);
disp(phi_max,'flux(Wb)');
B_max=phi_max/(b1*b2);
disp(B_max,'B_max(T)');

H_max=250;          //According to B_max, H_max is 250
   AT/m
l_c=.2*(3.0+3.5);     //length of core
AT_max=H_max*l_c;
disp(AT_max,'AT_max');
T_max=N1;
I_mmax=AT_max/T_max;
I_mrms=I_mmax/2^.5;
disp(I_mrms,'I_mrms(A)');

v=2*(20*10*5)+2*(45*10*5);

d=.0079;             //density of core material
w=v*d;

cl=3;                //core loss/kg
closs=w*cl;
disp(closs,'core loss(W)');
I_i=closs/E;
disp(I_i,'I_i(A)');
function [r,pff]=rect2polar(x,y)
    r=sqrt(x^2+y^2);
    pff=cosd(atand(y/x));
endfunction
```

```
[I_o,pf]=rect2polar(I_i,-I_mmax);
disp(I_o,'no load current(A)');
disp(pf,'no load power factor');
```

Scilab code Exa 3.3 To calculate primary and scondary side impedences current and their pf and real power and calculate terminal voltage

```
// To calculate primary and scondary side impedences
    ,current and their pf and real power
// and calculate terminal voltage

clc;
N_1=150;
N_2=75;

a=N_1/N_2;

Z_2=[5,30];                    //polar(magnitude,phase
    diff)
disp(Z_2,'secondary impedence(ohm)');
Z_1=[a^2*Z_2(1),Z_2(2)];
disp(Z_1,'primary impedence(ohm)');

V_1=[200,0];                   //polar(magnitde,phase
    diff)
V_2=[V_1(1)/a,V_1(2)];
disp(V_2,'secondary terminal voltage(V)');

I_2(1)=V_2(1)/Z_2(1);
I_2(2)=V_2(2)-Z_2(2);
disp(I_2,'I_2=');
pf=cosd(I_2(2));
disp(pf,'pf lagging=');

I_1(1)=I_2(1)/a;
```

```
I_1(2)=I_2(2);
disp(I_1,'I_1(A)');
pf=cosd(I_1(2));
disp(pf,'pf lagging=');

P_2=V_2(1)*I_2(1)*cosd(I_2(2));
disp(P_2,'secondary power output(W)=');
//P_1=primary power output
P_1=P_2                                   //as the
    transormer is lossless
disp(P_1,'primary power output(W)=');
```

Scilab code Exa 3.4 To calculate primary current and its pf

```
// To calculate primary current and its pf

clc;

function [x,y]=polar2rect(r,theta)
    x=r*cosd(theta);
    y=r*sind(theta);
endfunction

function [r,theta]=rect2polar(x,y)
    r=sqrt(x^2+y^2);
    theta=atand(y/x);
endfunction

I_2=[10 -30];
[I_2r(1),I_2r(2)]=polar2rect(I_2(1),I_2(2));

I_0=[1.62 -71.5];
[I_0r(1),I_0r(2)]=polar2rect(I_0(1),I_0(2));

I_1r=I_0r+I_2r;
```

```

[I_1(1),I_1(2)]=rect2polar(I_1r(1),I_1r(2));
disp(I_1(1),'primary current(A)=');
pf=cosd(I_1(2));
disp(pf,'power factor=');
```

Scilab code Exa 3.5 Equivalent circuit referred to HV side LV side

```
// Equivalent circuit referred to(i)HV side (ii)LV
   side

clc;

N_1=2000;
N_2=200;

a=N_1/N_2;

Z_2=complex(.004,.005);              //low voltage
   impedence
Z_2hv=a^2*Z_2;
disp(Z_2hv,'Z_2 referred to hv side(ohm)');
                                //when referred to hv side

Y_0=complex(.002,-.015);             //shunt branch
   admittance
Y_0hv=Y_0/a^2;
disp(Y_0hv,'Y_0 referred to hv side(mho)');

Z_1=complex(.42,.52);                //low voltage
   impedence
Z_1lv=Z_1/a^2;
disp(Z_1lv,'Z_1 referred to lv side(ohm)');
```

Scilab code Exa 3.6 To find the voltage at the load end of the transformer when load is drawing transformer current

```
// To find the voltage at the load end of the transformer when load is drawing transformer current

clc;

I=20/2;                         //rated load current(hv side)

Z1=[.25,1.4];                           //impedence of feeder      (REAL,IMAGINERY)
Z2=[.82,1.02];                          //impedence of transformer     (REAL,IMAGINERY)

Z=Z1+Z2;
disp(Z,'Z(ohm)');

pf=.8;
phi=acosd(pf);

//from phasor diagram

R=Z(1);
X=Z(2);
AF=I*X*cosd(phi);
FE=I*R*sind(phi);
AE=AF-FE;
OA=2000;
OE=sqrt(OA^2-AE^2);

BD=I*R*cosd(phi);
```

```
DE=I*X*sind(phi);
BE=BD+DE;
V1=OE;    disp(V1,'V1(V)');
V2=V1-BE;     disp(V2,'V2(V)');

loadvol=V2/10;                              //referred to
   LV side
disp(loadvol,'load voltage(V)');
```

Scilab code Exa 3.7 Approx equivalent ckt referred to hv and lv sides resp

```
// Approx equivalent ckt referred to hv and lv sides
    resp,

clc;
//open ckt test data with HV side open
ocv=200;
oci=4;
ocp=120;
//short ckt test data with LV side open
scv=60;
sci=10;
scp=300;
//OC test(LV side)
Y_o=oci/ocv;     disp(Y_o,'Y_o(mho)');
G_i=ocp/ocv^2;   disp(G_i,'G_i(mho)');
B_m=sqrt(Y_o^2-G_i^2);    disp(B_m,'B_m(mho)');
//SC test(HV side)
Z=scv/sci;        disp(Z,'Z(ohm)');
R=scp/sci^2;      disp(R,'R(ohm)');
X=sqrt(Z^2-R^2);    disp(X,'X(ohm)');

N_H=2000;
N_L=200;
a=N_H/N_L;                                  //
```

```
    transformation ratio

//Equivalent ckt referred to HV side
G_iHV=G_i/a^2;         disp(G_iHV,'G_i(HV)mho');
B_mHV=B_m/a^2;         disp(B_mHV,'B_m(HV)mho');

//Equivalent ckt referred to LV side
RLV=R/a^2;         disp(RLV,'R(LV)ohm');
XLV=X/a^2;         disp(XLV,'X(LV)ohm');
```

Scilab code Exa 3.8 to calculate open ckt current power and pf when LV excited at rated voltage voltage at which HV side is excited ip power and its pf

```
// to calculate (a)open ckt current,power and pf
    when LV excited at rated voltage
// (b) voltage at which HV side is excited, ip power
     and its pf

clc;
r=150000;                                          //
    rating(VA)
V1=2400;
V2=240;
a=V1/V2;

R_1=.2;
X_1=.45;
R_i=10000;
R_2=2*10^-3;
X_2=4.5*10^-3;
X_m=1600;
//Referring the shunt parameters to LV side
R_iLV=R_i/a^2;
X_mLV=X_m/a^2;
```

```
I_oLV=[V2/100 V2/16];
I_o=sqrt(I_oLV(1)^2+I_oLV(2)^2);    disp(I_o,'I_o(A)
  ');
pf=cosd(atand(I_oLV(2)/I_oLV(1)));    disp(pf,'pf');
//equivalent series parameters referred to HVside
R=R_1+R_2*a^2;
X=X_1+X_2*a^2;
Z=complex(R,X);    disp(Z,'Z(ohm)');
z=[R X];
I_flHV=r/V1;
V_scHV=I_flHV*sqrt(R^2+X^2);
P_sc=I_flHV^2*R;    disp(P_sc,'P_sc(W)');
pf_sc=cosd(atand(X/R));    disp(pf_sc,'pf_sc');
```

Scilab code Exa 3.10 To find exciting current and expess impedence in pu in both HV and LV sides

```
//To find exciting current and expess impedence in
  pu in both HV and LV sides

clc;

V_BHV=2000;
I_BHV=10;
Z_BHV=V_BHV/I_BHV;

V_BLV=200;
I_BLV=100;
Z_BLV=V_BLV/I_BLV;

I_o=3;
a=V_BHV/V_BLV;

I_oLV=I_o/100;    disp(I_oLV,'I_o(LV)pu=');
I_oHV=I_o/(a*10);    disp(I_oHV,'I_o(HV)pu=');
```

```
Z=complex(8.2,10.2);
ZHV=Z/Z_BHV;      disp(ZHV,'Z(HV)pu=');
z=Z/a^2;
ZLV=z/Z_BLV;      disp(ZLV,'Z(LV)pu=');
```

Scilab code Exa 3.11 o calculate efficiency of transformer

```
// To calculate efficiency of transformer

clc;

V_2=200;
I_2=100;
pf=.8;
P_o=V_2*I_2*pf;              //power output

P_i=120;
P_c=300;
k=1;
P_L=P_i+k^2*P_c;              //total losses

n=1-(P_L/(P_o+P_L));        disp(n*100,'n(%)');

K=sqrt(P_i/P_c);              //max efficiency

n_max=1-(2*P_i/(P_o*K+2*P_i));          //pf=.8
disp(n_max*100,'n_max(%)');
```

Scilab code Exa 3.13 comparing all day efficiencies for diff given load cycles

```
// Comparing all-day efficiencies for diff given load cycles

clc;

r=15;               // kva rating
n_max=.98;
pf=1;
P_o=20;
P_i=r*(1-n_max)/2;
k=r*pf/P_o;
P_c=P_i/(k^2);
function [W_o,W_in]=power(P_o,h)
    k=P_o/20;
    P_c=P_i*P_o/r;
    W_o=P_o*h;
    W_in=(P_o+P_i+(k^2)*P_c)*h;
endfunction

//(a)full load of 20kva 12hrs/day and no load rest of the day
a=[20 12];
[W_oa(1),W_ina(1)]=power(a(1),a(2));
aa=[0 12];
[W_oa(2),W_ina(2)]=power(aa(1),aa(2));
disp(W_oa,'W_o(kWh) for a');
disp(W_ina,'W_in(kWh) for a');
n_ada=sum(W_oa)/sum(W_ina);    disp(n_ada*100,'n_allday(a) in %age');

//(b)full load of 20kva 4hrs/day and .4 of full load rest of the day
b=[20 4];
[W_ob(1),W_inb(1)]=power(b(1),b(2));
bb=[8 20];
[W_ob(2),W_inb(2)]=power(bb(1),bb(2));
disp(W_ob,'W_o(kWh) for b');
disp(W_inb,'W_in(kWh) for b');
```

```
n_adb=sum(W_ob)/sum(W_inb);     disp(n_adb*100,'n_allday(b) in %age');
```

Scilab code Exa 3.14 To calculate volatage regulation volatage at load terminals and operating efficiency

```
// To calculate volatage regulation , volatage at load terminals and operating efficiency

clc;
S=20*1000;
V1=200;
V2=2000;
I1=S/V1;
I2=S/V2;
Rh=3;
Xh=5.2;
pf=0.8;
phi=acosd(pf);
Vha=V2+I2*(Rh*cosd(phi)+Xh*sind(phi));          // lagging
Vrega=(Vha-V2)*100/V2;      disp(Vrega,'vol-reg lagging(%)');
Vhb=V2+I2*(Rh*cosd(phi)-Xh*sind(phi));          // leading
Vregb=(Vhb-V2)*100/V2;      disp(Vregb,'vol-reg leading(%)');

V11=V2-I2*(Rh*cosd(phi)+Xh*sind(phi));
v1=V11/I2;          disp(v1,'V_L(V)');
ploss=120+10*10*3;
pop=v1*I1*cosd(phi);
eff=(1-(ploss/(ploss+pop)))*100;
disp(eff,'eff(%)');
```

Scilab code Exa 3.15 To determine voltage regulation and efficiency

```
// To determine voltage regulation and efficiency

clc;

r=150*1000;                    //rating in va
v1=2400;
v2=240;
a=v2/v1;
R_hv=.2+.002/a^2;
X_hv=.45+.0045/a^2;
I_2fl=r/v2;
pf=0.8        //lagging
phi=acosd(pf);
I_2=I_2fl*a;
vd=I_2*(R_hv*cosd(phi)+X_hv*sind(phi));
V2=v1;
vr=(vd/V2)*100;       disp(vr,'vol reg(%)');
V1=v1+vd;
P_out=r*pf;
P_c=(I_2^2)*R_hv;       //copper loss
P_i=(V1^2)/10000;
P_L=P_c+P_i;
n=P_out/(P_out+P_L);       disp(n*100,'eff(%)');

I_o(1)=V1/(10*1000);
I_o(2)=-V1/(1.6*1000);       //inductive effect
I2(1)=I_2*(cosd(phi));
I2(2)=I_2*(-sind(phi));
I_1=I_o+I2;
b=sqrt(I_1(1)^2+I_1(2)^2);
disp(b,'I_1(A)');
pff=cosd(atand(I_1(2)/I_1(1)));
```

```
disp(pff,'pf');
```

Scilab code Exa 3.16 to calculate voltage ratings kva ratings and efficieny of autotransformer

```
// to calculate voltage ratings ,kva ratings and efficieny of autotransformer

clc;

AB=200;
BC=2000;
V_1=BC;          disp(V_1,'V_1(V)');
V_2=AB+BC;       disp(V_2,'V_2(V)');
r=20000;                //rating of transformer
I_2=r/AB;
I_1=I_2+10;
rr=V_2*I_2/1000;            //kva rating of autotransformer
disp(rr,'kva rating');
ri=V_1*(I_1-I_2)/1000;      //kva inductive
rc=rr-ri;
disp(ri,'kva transferred inductively');
disp(rc,'kva transferred conductively');
W_c=120;                //core loss
W_cu=300;                //cu loss
W_t=W_c+W_cu;            //total loss
pf=0.8;
W=V_2*I_2*pf;            //full load output
n=1-(W_t/W);
disp(n*100,'eff(%)');
```

Scilab code Exa 3.17 To determine the rating and full load efficiency of autotransformer

```
// To determine the rating and full load efficiency
   of autotransformer

clc;
//when used as transformer
v1=240;
v2=120;
r=12000;
I1=r/v1;
I2=r/v2;

//when connected as autotransformer
V1=240;
V2=v1+v2;
rr=I2*V2;            disp(rr,'rating of
   autotransformer(va)');

pf=1;
P_o=r*pf;            //output power
n=.962            //efficiency at upf
P_L=P_o*(1-n)/n;

pff=.85             //if pf=.85
Po=rr*pff;
nn=1/(1+P_L/Po);          disp(nn*100,'efficiency(%)
   at .85 pf is');
```

Scilab code Exa 3.18 To calculate sec line voltage line current and output va

```
// To calculate sec. line voltage, line current and
   output va
```

```
clc;

disp('(a)Y/D conn');
V_LY=6600;
V_PY=V_LY/sqrt(3);
a=12;
V_PD=V_PY/a;
V_LD=V_PD;    disp(V_LD,'sec line voltage(V)');

I_PY=10;
I_PD=I_PY*a;
I_LD=I_PD*sqrt(3);    disp(I_LD,'sec. line current(A
   )');
r=sqrt(3)*V_LD*I_LD;    disp(r,'output rating(va)');

disp('(b)D/Y conn');
I_LD=10;
I_PD=I_LD/sqrt(3);
I_LY=I_PD*a;        disp(I_LY,'sec. line current(A)'
   );
V_PD=6600;
V_PY=V_PD/a;
V_LY=V_PY*sqrt(3);    disp(V_LY,'sec line voltage(V)
   ');
r=sqrt(3)*V_LY*I_LY;    disp(r,'output rating(va)');
```

Scilab code Exa 3.19 To compute all the currents and voltages in all windings of Y D transformer

```
// To compute all the currents and voltages in all
   windings of Y/D transformer

clc;

```

```
S=complex(500,100);          //load is 500MW and 100 MVar
s=abs(S);
r=s/3;          //MVA rating of each single ph transformer

V1=22;          //D side
V2=345;          //Y side
a=V2/(sqrt(3)*V1);          //voltage rating of each single phase
disp('Y side');
V_A=(V2/sqrt(3))*complex(cosd(0),sind(0));
V_B=(V2/sqrt(3))*complex(cosd(-120),sind(-120));
V_C=(V2/sqrt(3))*complex(cosd(-240),sind(-240));

V_AB=V_A-V_B;     disp(V_AB,'V_AB(V)');
V_BC=V_B-V_C;     disp(V_BC,'V_BC(V)');
V_CA=V_C-V_A;     disp(V_CA,'V_CA(V)');

IA=S/(3*V_A);     disp(IA,'IA(A)');
IB=S/(3*V_B);     disp(IB,'IB(A)');
IC=S/(3*V_C);     disp(IC,'IC(A)');
disp('D side');
V_ab=V_A/a;     disp(V_ab,'V_ab(V)');
V_bc=V_B/a;     disp(V_bc,'V_bc(V)');
V_ca=V_C/a;     disp(V_ca,'V_ca(V)');

I_ab=a*IA;
I_bc=a*IB;
I_ca=a*IC;
Ia=I_ab-I_bc;     disp(Ia,'Ia(A)');
Ib=I_bc-I_ca;     disp(Ib,'Ib(A)');
Ic=I_ca-I_ab;     disp(Ic,'Ic(A)');
```

Scilab code Exa 3.20 to find the load voltage when it draws rated current from transformer

```
// to find the load voltage when it draws rated
   current from transformer

clc;
// here pu method is used
r=20;          //kva rating of three 1-ph transformer
MVA_B=r*3/1000;
v2=2*sqrt(3);          //in kv voltage base on hv side
v1=.2;          //in kv voltage base on lv side

z1=complex(.0004,.0015);          //feeder impedence
Z1=z1*MVA_B/v1^2;          // lv line(pu)
z2=complex(.13,.95);          //load impedence
Z2=z2*MVA_B/v2^2;          // hv line(pu)
z_T=complex(.82,1.02);
ZTY=z_T*MVA_B/v2^2;          // star side(pu)

Ztot=Z1+Z2+ZTY;
V1=1;          //sending end voltage [pu]
I1=1;          //rated current(pu)
pf=.8;
V2=V1-I1*(real(Ztot)*pf+imag(Ztot)*.6);          //
   load voltage(pu)
V2v=V2*v1;
disp(V2v,'load voltage(kv)');
```

Scilab code Exa 3.21 to calculate fault currentin feeder lines primary and secondary lines of receiving end transformers

```
// to calculate fault currentin feeder lines,primary
    and secondary lines of receiving end
   transformers
```

```
clc;

r=60;          //kva rating of 3-ph common base
s=200;          //kva rating of 3ph transformer
//sending end
X_Tse=.06*r/s;     //.06= reactance of transformer
   based on its own rating
//in 2 kv feeder
V_B=2000/sqrt(3);     //line to neutral
I_B=r*1000/(sqrt(3)*2000);
Z_B=V_B/I_B;
X_feeder=0.7/Z_B;         //feeder reactance=0.7
//receiving end
X_Tre=0.0051;
X_tot=X_Tse+X_feeder+X_Tre;
V_se=20/20;
I_fc=V_se/X_tot;     //feeder current

I_f=I_fc*I_B;     disp(I_f,'current in 2kv feeder(A)'
   );
I_t1=I_f/sqrt(3);     disp(I_t1,'current in 2kv
   winding of transformer(A)');
I_t2=I_t1*10;     disp(I_t2,'current in 200kv winding
    of transformer(A)');
I_l=I_t2*sqrt(3);     disp(I_l,'current at load
   terminals(A)');
```

Scilab code Exa 3.22 To calculate voltage and kva rating of 1ph transformer

```
// To calculate voltage and kva rating of 1-ph
   transformer

clc;
```

```

V_p=33;     //primary side voltage(V)
V_s=11;     //secondary side voltage(V)
V_p1=V_p/sqrt(3);     //per ph primary side voltage(V
    )
V_p2=V_s/sqrt(3);     //per ph secondary side voltage
    (V)

r=6000;     //kva rating 3-ph
s=r/3;     //per phase
disp('Y/Y conn');
disp(V_p1,'primary side ph voltage(V)');
disp(V_p2,'secondary side ph voltage(V)');
disp(s,'kva rating of transformer');

disp('Y/D conn');
disp(V_p1,'primary side ph voltage(V)');
disp(V_s,'secondary side ph voltage(V)');
disp(s,'kva rating of transformer');

disp('D/Y conn');
disp(V_p,'primary side ph voltage(V)');
disp(V_p2,'secondary side ph voltage(V)');
disp(s,'kva rating of transformer');

disp('D/D conn');
disp(V_p,'primary side ph voltage(V)');
disp(V_s,'secondary side ph voltage(V)');
disp(s,'kva rating of transformer');
```

Scilab code Exa 3.23 to calculate reactance in ohms line voltage kva rating series reactance for YY and YD conn

```
// to calculate (a)reactance in ohms(b)line voltage,
    kva rating,series reactance for Y/Y  and Y/D
```

```
conn

clc;
Xpu=0.12;     // of 1-ph transformer

function [X]=Xohm(kv,MVA)
    X=(Xpu*kv^2)/MVA;
endfunction

disp('(a)');
MVAa=75*10^-3;
Vhv=6.6;
Vlv=.4;
Xhv=Xohm(Vhv,MVAa);      disp(Xhv,'X(ohm) of hv side');
Xlv=Xohm(Vlv,MVAa);      disp(Xlv,'X(ohm) of lv side');

disp('(b)');
disp('Y/Y');
MVAb=MVAa*3;
Vhv=6.6*sqrt(3);     disp(Vhv,'V_hv(kV)');
Vlv=.4*sqrt(3);      disp(Vlv,'V_lv(kV)');
Xhv=Xohm(Vhv,MVAb);      disp(Xhv,'X(ohm) of hv side');
Xlv=Xohm(Vlv,MVAb);      disp(Xlv,'X(ohm) of lv side');

disp('Y/D');
MVAb=MVAa*3;
Vhv=6.6*sqrt(3);     disp(Vhv,'V_hv(kV)');
Vlv=.4;              disp(Vlv,'V_lv(kV)');
Xhv=Xohm(Vhv,MVAb);      disp(Xhv,'X(ohm) of hv side');
Xlv=Xohm(Vlv,MVAb);      disp(Xlv,'X(ohm) of lv side');
```

Scilab code Exa 3.24 find how 2 transformers connected in parallel share the load

```
//find how 2 transformers connected in parallel
   share the load

clc;
Z1=complex(.012,.06);
Z2=2*complex(.014,.045);
Z=Z1+Z2;
r=800;          //kva rating
pf=.8;
S_L=r*(complex(pf,-1*sind(acosd(pf))));
S_1=S_L*Z2/Z;disp(S_1,'load by first transformer(kVA
   )');
S_2=S_L*Z1/Z;disp(S_2,'load by second transformer(
   kVA)');

S_2rated=300;
S_Lmax=S_2rated*abs(Z)/abs(Z1);
disp(S_Lmax,'max load by both transformer(kVA)');

r1=600;          //kva
V=440;
Z1actual=Z1*V/(r1*1000/V);
Z2actual=Z2*V/(r1*1000/V);
Zactual=Z1actual+Z2actual;
Z_Lact=V^2/(S_L*1000);

V1=445;
I1=(V1*Z2actual-10*Z_Lact)/(Z1actual*Z2actual+Z_Lact
   *Zactual);
I2=(V1*-1*Z1actual-10*Z_Lact)/(Z1actual*Z2actual+
   Z_Lact*Zactual);
```

```
S1=V*I1/1000;     disp(S1,'kVA of first transformer');
S2=V*I2/1000;     disp(S2,'kVA of second transformer');
Pout=abs(S1)*cosd(atand(imag(S1)/real(S1)))+abs(S2)*cosd(atand(imag(S2)/real(S2)));
disp(Pout,'total output power(kW)');
```

Scilab code Exa 3.25 find pu value of the equivalent ckt steady state short ckt current and voltages

```
//find pu value of the equivalent ckt,steady state short ckt current and voltages

clc;
r=5;            //MVA rating
V_Bp=6.35;      //for primary
I_Bp=r*1000/V_Bp;
V_Bs=1.91;      //for secondary
I_Bs=r*1000/V_Bs;
//from resp tests
V1=.0787;
I1=.5;
V2=.1417;
I2=.5;
V3=.1212;
I3=.5;
X12=V1/I1;
X13=V2/I2;
X23=V3/I3;
X1=I1*(X12+X13-X23);
X2=I2*(X23+X12-X13);
X3=I3*(X13+X23-X12);
disp(X1,'X1(pu)');
disp(X2,'X2(pu)');
```

```
disp(X3,'X3(pu)');

V1=1;
I_sc=V1/X13;
I_scp=I_sc*I_Bp;    disp(I_scp,'sc current primary side(A)');
I_sct=I_sc*r*1000*1000/(400/sqrt(3));    disp(I_sct,'sc current tertiary side(A)');
V_A=I_sc*X3;
V_Aact=V_A*1.91*sqrt(3);
disp(V_Aact,'V_A(actual) line to line(kV)');
```

Scilab code Exa 3.26 to calculate line currents of 3 ph side

```
// to calculate line currents of 3 ph side

clc;
N1=6600;
N2=100;
a=N1/N2;
b=(sqrt(3)/2)*a;
P=400;    //kW
pfa=.707;
pfb=1;
V=100;
Ia=P*1000/(V*pfa);
Ib=P*2*1000/(V*pfb);
I_A=Ia/b;disp(I_A,'I_A(A)');
I_BC=Ib/a;
I_B=I_BC-49.5*complex(pfa,pfa);    disp(abs(I_B),'I_B(A)');
I_C=I_BC+49.5*complex(pfa,-1*pfa);disp(abs(I_C),'I_C(A)');
```

Scilab code Exa 3.27 to calculate magnitude and phase of secondary current

```
//to calculate magnitude and phase of secondary
   current

clc;
X1=505;     //uohm
X2=551;     //uohm
R1=109;     //uohm
R2=102;     //uohm
Xm=256;     //mohm
I1=250;     //A
I22=complex(0,Xm*1000)*I1/(complex(R1,X2+Xm*1000));
N1=250;
N2=5;
I2=I22*(N2/N1);
disp(abs(I2),'current magnitude(A)');
disp(atand(imag(I2)/real(I2)),'phase(degree)');
disp('now Rb is introduced in series');
Rbb=200;     //uohm
Rb=(N2/N1)^2*Rbb;
I22=complex(0,Xm*1000)*I1/(complex((R1+Rb),X2+Xm
   *1000));
I2=I22*(N2/N1);
disp(abs(I2),'current magnitude(A)');
disp(atand(imag(I2)/real(I2)),'phase(degree)');
disp('no chnage as Rb is negligible');
```

Scilab code Exa 3.28 to calculate sec voltage magnitude and ph

```
//to calculate sec voltage magnitude and ph
```

```
clc;
a=6000/100;     //turn ratio
R1=780;
R2=907;
X1=975;
X2=1075;
Xm=443*1000;
disp('sec open');
//Zb=inf;
V1=6500;
V22=complex(0,Xm)*V1/complex(R1,Xm);
V2=V22/a;
disp(abs(V2),'voltage magnitude(V)');
disp(atand(imag(V2)/real(V2)),'phase(deg)');

disp('when Zb=Rb');
Rb=1;
Rbb=Rb*a^2;
Zm=complex(0,Xm/1000)*Rbb/complex(0,Xm/1000)+Rbb;
R=complex(R1/1000,X1/1000)+Zm;
Vm=Zm*V1/R;
V2=Vm/a;
disp(abs(V2),'voltage magnitude(V)');
disp(atand(imag(V2)/real(V2)),'phase(deg)');

disp('when Zb=jXb');
Rb=complex(0,1);
Rbb=Rb*a^2;
Zm=complex(0,Xm/1000)*Rbb/complex(0,Xm/1000)+Rbb;
R=complex(R1/1000,X1/1000)+Zm;
Vm=Zm*V1/R;
V2=Vm/a;
disp(abs(V2),'voltage magnitude(V)');
disp(atand(imag(V2)/real(V2)),'phase(deg)');
```

Scilab code Exa 3.29 to calculate L1 and L2 and coupling cofficient

```
//to calculate L1 and L2 and coupling cofficient

clc;
a=10;
V_p=200;
I_p=4;
Xm=V_p/I_p;
f=50;
L1=Xm/(2*%pi*f);disp(L1,'L1(H)');
V_s=1950;
w_max=V_s/(sqrt(2)*%pi*f);
M=w_max/(sqrt(2)*I_p);

v_s=2000;
i_s=.41;
w_max=sqrt(2)*i_s*M;
E1=sqrt(2)*%pi*f*w_max;
L2=v_s/(sqrt(2)*%pi*f*sqrt(2)*i_s);disp(L2,'L2(H)');
k=M/(sqrt(L1)*sqrt(L2));disp(k,'coupling coeff');
```

Scilab code Exa 3.30 to calculate leakage inductance magnetisisng inductance mutual inductance and selfinductance

```
// to calculate leakage inductance, magnetisisng
   inductance,mutual inductance and self-inductance

clc;
V1=2400;
V2=240;
a=V1/V2;
```

```
R1=.2;
X1=.45;
Rl=10000;
R2=2*10^-3;
X2=4.5*10^-3;
Xm=1600;
f=50;
l1=X1/(2*%pi*f);disp(l1,'leakage inductance ie l1(H)
    ');
l2=X2/(2*%pi*f);disp(l2,'l2(H)');
Lm1=Xm/(2*%pi*f);disp(Lm1,'magnetising inductance(H)
    ');
L1=Lm1+l1;disp(L1,'self-inductance ie L1(H)');
M=Lm1/a;
L2=l2+M/a;disp(L2,'L2(H)');
k=M/sqrt(L1*L2);disp(k,'coupling factor');
```

Scilab code Exa 3.31 to calculate percentage voltage reg and efficiency

```
//to calculate %voltage reg and efficiency

clc;
P=500000;
V1=2200;
V2=1100;
V0=110;
I0=10;
P0=400;
Y0=I0/V0;
Gi=P0/(V0^2);
Bm=sqrt(Y0^2-Gi^2);
Vsc=90;
Isc=20.5;
Psc=808;
Z=Vsc/Isc;
```

```
R=Psc/Isc^2;
X=sqrt(Z^2-R^2);
TR=V1/V2;
Gi_HV=Gi/TR^2;
Bm_HV=Bm/TR^2;
R_LV=R/TR^2;
X_LV=X/TR^2;
I2=P/V2;
pf=.8;
Th=acos(pf);
dV=I2*(R_LV*cos(Th)+X_LV*sin(Th));
VR=(dV/V2)*100;     disp(VR,'voltage regulation(%)');
Pi=P0;
Pc=Psc;
n=P*100/(P+Pi+Pc);disp(n,'eff(%)');
```

Chapter 5

Basic Concepts in Rotating Machines

Scilab code Exa 5.1 To calculate harmanic factor for stator

```
// To calculate harmanic factor for stator

clc;
S=36;     //no of slots
q=3;     //no of phases
p=4;     //no of poles
m=S/(q*p);     //slots/pole/phase
g=180*p/S;     //gamma elec
function [k]=bfctr(n)
    k=sind(m*n*g/2)/(m*sind(n*g/2));
endfunction

K_b=bfctr(1);
disp(K_b,'K_b(fundamental)');

K_b=bfctr(3);
disp(K_b,'K_b(third harmonic)');

K_b=bfctr(5);
```

```
disp(K_b,'K_b(fifth harmonic)');
```

Scilab code Exa 5.2 to find the frequency and phase and line voltages

```
// to find the frequency and phase and line voltages

clc;
n=375;          //speed in rpm
p=16;          //no of poles
f=n*p/120;
disp(f,'freq(Hz)');
S=144;          //no of slots
c=10;          //no of conductors/slot
t=S*c/2;          //no of turns
ph=3;
N_ph=t/ph;      //no of turns/ph
g=180*p/S;      //slots angle
m=S/(p*ph);     //slots/pole/phase
K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
phi=0.04;      //flux per pole
E_p=4.44*K_b*f*N_ph*phi;
disp(E_p,'phase voltage(V)');
E_l=sqrt(3)*E_p;
disp(E_l,'line voltage(V)');
```

Scilab code Exa 5.3 to find the phase and line voltages

```
// to find the phase and line voltages

clc;
f=50;     //freq
n=600;     //speed in rpm
p=120*f/n;
```

```
ph=3;
m=4;          //slots/pole/ph
S=p*ph*m;     //slots
t=12;         //turns per coil
N_ph=S*t/ph;
g=180*p/S;
K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
cp=10;          //coil pitch
pp=S/cp;          //pole pitch
theta_sp=(pp-cp)*g;     //short pitch angle
K_p=cosd(theta_sp/2);
phi=.035;
E_p=4.44*K_b*K_p*f*N_ph*phi;
disp(E_p,'phase voltage(V)');
E_l=sqrt(3)*E_p;
disp(E_l,'line voltage(V)');
```

Scilab code Exa 5.4 to calculate flux per pole

```
// to calculate flux/pole

clc;
S=42;
p=2;
ph=3;
m=S/(p*ph);     //slots/pole/phase
g=180*p/S;     //slots angle
K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
cp=17;
pp=S/p;
theta_sp=(pp-cp)*g;     //short pitch angle
K_p=cosd(theta_sp/2);
N_ph=S*2/(ph*p*2);          //2 parallel paths
E_p=2300/sqrt(3);
phi=E_p/(4.44*K_b*K_p*f*N_ph);
```

```
disp(phi,'flux/pole(Wb)');
```

Scilab code Exa 5.5 to calculate useful flux per pole and ares of pole shoe

```
// to calculate  useful flux/pole and ares of pole
   shoe

clc;
p=1500*1000;     //power
v=600;
I_a=p/v;
cu=25*1000;     //copper losses
R_a=cu/I_a^2;
E_a=v+I_a*R_a;
n=200;
Z=2500;
p=16;
A=16;
phi=E_a*60*A/(p*n*Z);
disp(phi,'flux/pole(Wb)');
fd=0.85;     //flux density
a=phi/fd;
disp(a,'area of pole shoe(m*m)');
```

Scilab code Exa 5.6 To calculate em power developed mech power fed torque provided by primemover

```
// To calculate em power developed,mech power fed,
   torque provided by primemover

clc;
phi=32*10^-3;      //flux/pole
n=1600;          //speed in rpm
```

```
Z=728;          //no of conductors
p=4;
A=4;
E_a=phi*n*Z*(p/A)/60;
I_a=100;
P_e=E_a*I_a;
disp(P_e,'electromagnetic power(W)');
P_m=P_e;
disp(P_m,'mechanical power(W) fed');
w_m=2*%pi*n/60;
T=P_m/w_m;
disp(T,'primemover torque(Nm)');
```

Scilab code Exa 5.9 To determine peak value of fundamental mmf

```
// To determine peak value of fundamental mmf

clc;
f=50;
n_s=300;
p=120*f/n_s;
P=400*1000;     //power
V=3300;
I_L=P/(sqrt(3)*V);
I_P=I_L;
I_m=sqrt(2)*I_P;     //max value of phase current
S=180;
g=180*p/S;
ph=3;
m=S/(p*ph);     //slots/pole/phase
K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
c=8;          //conductors/1 coil side
N_ph=S*c/(ph*2);       //turns/phase
F_m=(4/%pi)*K_b*(N_ph/p)*I_m;
F_peak=(3/2)*F_m;
```

```
disp(F_peak,'peak mmf(AT/pole)');
```

Scilab code Exa 5.10 to calculate field current and flux per pole and to calculate open ckt ph and line voltages and to caculate field current

```
// (a)to calculate field current and flux/pole(b)to
    calculate open ckt ph and line voltages
// (c)to caculate field current

clc;
B_peak=1.65;
g=.008;
u_o=4*%pi*10^-7;
P=4;
K_b=.957;
N_field=364/2;
I_f=B_peak*%pi*g*P/((4*u_o)*(K_b*N_field));
disp(I_f,'field current(A)');
l=1.02;     //rotor length
r=.41/2;     //rotor radius
phi=(4/P)*B_peak*l*r;
disp(phi,'flux/pole(Wb)');
N_ph=3*11*P/2;
ga=60/3;     //slot angle
m=3;
f=50;
K_b=sind(m*ga/2)/(m*sind(ga/2));     //breadth factor
E_ph=sqrt(2)*%pi*K_b*f*N_ph*phi;
disp(E_ph,'E_ph(V)');
E_line=sqrt(3)*E_ph;
disp(E_line,'E_line(V)');
I_fnew=.75*I_f;
disp(I_fnew,'I_f(new)(A)');
```

Scilab code Exa 5.11 to find fundamental mmf wave speed and its peak value

```
// to find fundamental mmf wave,speed and its peak
   value

clc;
p=4;
S=60;
g=180*p/S;
ph=3;
m=S/(p*ph);     //slots/pole/phase
K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
I_L=48;
I_P=I_L/sqrt(3);
I_Pmax=I_P*sqrt(2);
c=24;           //conductors
N_ph=S*c/(ph*2);        //turns/phase
F_m=(4/%pi)*K_b*(N_ph/p)*I_Pmax;
disp(F_m,'F_m(AT/pole)');
F_peak=(3/2)*F_m;
disp(F_peak,'F_peak(AT/pole)');
n=120*f/P;
disp(n,'speed(rpm)');
```

Scilab code Exa 5.12 to calculate resultant air gap flux per pole

```
// to calculate resultant air gap flux/pole

clc;
F1=400;
F2=850;
```

```
a=123.6;
Fr=sqrt(F1^2+F2^2+2*F1*F2*cosd(a));
P=1.408*10^-4;          //permeance/pole
phi_r=P*Fr;
disp(phi_r,'air gap flux/pole(Wb)');
```

Scilab code Exa 5.13 To calculate resultant AT per pole and peak air gap flux density rotor AT per pole stator AT and its angle with the resultant AT stator currrent

```
//To calculate resultant AT/pole and peak air gap
   flux density, rotor AT/pole, stator AT and its
   angle with the resultant AT, stator currrent

clc;
ph=3;
S=36;
c=8*2;
p=4;
f=50;
N_ph=S*c/(ph*2);        //turns/phase
ga=180*p/S;
m=S/(p*ph);      //slots/pole/phase
K_b=sind(m*ga/2)/(m*sind(ga/2));     //breadth factor
V_L=400;
V_ph=V_L/sqrt(3);
phi_r=V_ph/(4.44*K_b*f*N_ph);
disp(phi_r,'phi_r(Wb/pole)');
D=.16;
l=0.12;
PA=%pi*l*D/4;           //pole area
B_rav=phi_r/PA;
B_rpeak=(%pi/2)*B_rav;
g=2*10^-3;
u_o=4*%pi*10^-7;
```

```
F_r=g*B_rpeak/u_o;
disp(F_r,'F_r(AT/pole)');
T=60;           //torque(Nm)
d=26;
F2=T/((%pi/2)*(p/2)^2*phi_r*sind(d));
disp(F2,'F2(AT/pole)');
F1=sqrt(F2^2+F_r^2-2*F2*F_r*sind(d));
disp(F1,'F1(AT/pole)');
w=acosd((F1^2+F_r^2-F2^2)/(2*F1*F_r));
disp(w,'angle(deg)');
K_w=K_b;
I_a=F1/((3/2)*(4*sqrt(2)/%pi)*K_w*(N_ph/p));
disp(I_a,'I_a(A)');
```

Scilab code Exa 5.14 to determine in F2 peak rotor AT max torque ele ip at max torque for motoring mode and open ckt voltage for generating mode

```
//to determine in F2,peak rotor AT, max torque, ele
   i/p at max torque(motoring mode),open ckt voltage
   (generating mode)

clc;
disp('motoring mode');
K_w=.976;
N_pole=746;
p=4;
I_f=20;
F2=(4/%pi)*K_w*(N_pole/p)*I_f;
disp(F2,'F2(AT)');
B_r=1.6;
D=.29;
l=.35;
T_max=(p/2)*(%pi*D*l/2)*F2*B_r;
disp(T_max,'T_max');
f=50;
```

```
w_m=4*%pi*f/p;
P_in=T_max*w_m;
disp(P_in,'P_in(W)');

disp('generating mode');
m=S/(3*p);
ga=180*p/S;
K_b=sind(30)/(3*sind(15/2));
K_w=K_b;
u_o=4*%pi*10^-7;
phi_r=((2*D*l/p)*(u_o/g))*F2;
N_ph=20*p*4/2;
E_ph=4.44*K_b*f*N_ph*phi_r;
E_l=sqrt(3)*E_ph;
disp(E_l,'E_l(V)');
```

Scilab code Exa 5.15 to find motor speed

```
// to find motor speed

clc;
n=1500;          //speed of sync generator
p=4;
f=n*p/120;

p_im=6;
n_s=120*f/p_im;
s=0.05;          //slip
n_im=(1-s)*n_s;
disp(n_im,'speed of induction motor(rpm)');
```

Scilab code Exa 5.16 to find voltage available bw slip rings and its freq

```
//to find voltage available b/w slip rings and its
   freq

clc;
disp('(a)');
f=50;
p=6;
n_s=120*f/p;
n=-1000;
s=(n_s-n)/n_s;
f_s=f*s;
disp(f_s,'slip freq(Hz)');
v2=100;
V2=s*v2;
disp(V2,'slip ring voltage(V)');

disp('(b)');
n=1500;
s=(n_s-n)/n_s;
f_s=abs(f*s);
disp(f_s,'slip freq(Hz)');
v2=100;
V2=s*v2;
disp(V2,'slip ring voltage(V)');
```

Scilab code Exa 5.18 to find no of poles slip and freq of rotor currents at full load motor speed at twice of full load

```
//to find no of poles, slip and freq of rotor
   currents at full load, motor speed at twice of
   full load

clc;
n_s=600;
f=50;
```

```
P=120*f/n_s;
disp(p,'no of poles');
n=576;
s=(n_s-n)/n_s;
disp(s,'slip');
f2=s*f;
n_r=s*n_s;
disp(n_r,'rotor speed wrt rotating field(rpm)');
ss=f2*s;
n=(1-ss)*n_s;
disp(n,'motor speed(rpm)');
nn=528;
s_old=s;
s_new=(n_s-nn)/n_s;
fac=s_new/s_old;
disp(fac,'factor is');
```

Scilab code Exa 5.19 to calculate amplitude of travelling wave mmf peak value of air flux density velocity of wave current freq at some desired velocity

```
// to calculate amplitude of travelling wave mmf,
   peak value of air flux density, velocity of wave,
    current freq at some desired velocity

clc;
K_w=.925;
N_ph=48;
I=750/sqrt(2);
wndnglgth=2;
wavelgth=wndnglgth/0.5;
p=2*wavelgth;
F_peak=(3/2)*(4*sqrt(2)/%pi)*K_w*(N_ph/p)*I;
disp(F_peak,'F_peak(A/m)');
g=.01;
u_o=4*%pi*10^-7;
```

```
B_peak=u_o*F_peak/g;
disp(B_peak,'B_peak(T)');
f=25;
B=.5;
v=f*B;     disp(v,'velocity(m/s)');
vv=72*10^3/3600;          //given velocity
f=vv/0.5;
disp(f,'freq(Hz)');
```

Chapter 7

DC Machines

Scilab code Exa 7.1 to calculate no of parrallel path

```
// to calculate no of parrallel path

clc;
S=12;          //no of commutator segments
P=4;
Y_cs=S/P;          //slots
Y_b=2*Y_cs+1;
y_f=Y_b-2;
disp(y_f,'no of parralel path');
```

Scilab code Exa 7.2 to find spacing bw brushes

```
// to find spacing b/w brushes

clc;
S=22;
P=4;
Y_cs=floor(S/P);
```

```
U=6;          //coil sides/slot
Y_b=Y_cs*U+1;
y_f=Y_b-2;
n=(1/2)*U*S;          //no of commutator segments
A=4;          //no of brushes
sp=n/A;
disp(sp,'spacing b/w adjacent brushes');
```

Scilab code Exa 7.3 to calculate relevant pitches for wave windings

```
//to calculate relevant pitches for wave windings

clc;
S=16;
P=6;
Y_cs=floor(S/P);
U=2;
Y_b=Y_cs*U+1;
C=16;
y_c=U*(C-1)/P;
y_f=2*y_c-Y_b;
disp(y_f,'no of pitches');
```

Scilab code Exa 7.4 to find distance bw brushes

```
// to find distance b/w brushes

clc;
S=28;
P=4;
U=8;
c=U*S/2;
y_c=2*(c-1)/P;
```

```
Y_c=55;
C=(P/2)*Y_c+1;
Y_cs=floor(S/P);
Y_b=Y_cs*U+1;
y_f=2*Y_c-Y_b;
d=C/P;
disp(d,'dis b/w brushes');
```

Scilab code Exa 7.5 to find the torque and gross mech power developed

```
// to find the torque and gross mech power developed

clc;
D=.3;
l=.2;
p=4;
fd=.4;          //flux density
phi=%pi*(D/p)*l*fd;         //flux/pole
n=1500;
Z=400;
A=4;
E_a=phi*n*Z*(p/A)/60;
I_a=25;
mp=E_a*I_a;
disp(mp,'gross mech power developed(W)');
T=mp/(2*%pi*n/60);
disp(T,'torque developed(Nm)');
```

Scilab code Exa 7.6 to calculate ratio of generator speed to motor speed

```
// to calculate ratio of generator speed to motor
   speed

```

```
clc;
V=220;
P=4000;
I_a=P/V;
r_a=.4;          //armature resistance
E_ag=V+I_a*r_a;
E_am=V-I_a*r_a;
a=1.1;          //phi_m/phi_g
n=(E_ag/E_am)*a;
disp(n,'n_g/n_m');
```

Scilab code Exa 7.7 to calculate speed of motor

```
// to calculate speed of motor

clc;
V=230;
R_f=115;          //field resistance
I_f=V/R_f;
P_g=100000;          //electric power (m/c running as
   generator)
I_L=P_g/V;
I_a=I_f+I_L;
R_a=.08;          //armature resitance
E_ag=V+I_a*R_a;
n_g=750;          //speed

P_m=9000;          //m/c running as motor
I_l=P_m/V;
I_A=I_l-I_f;
E_am=V-I_A*R_a;
n_m=(E_am/E_ag)*n_g;
disp(n_m,'motor speed(rpm)');
```

Scilab code Exa 7.8 to calculate electomagnetic power and torque

```
//to calculate electomagnetic power and torque

clc;
E_a=250;
R_a=.05;
n=3000;
w_m=(n*2*%pi)/60;
disp('when terminal voltage is 255V');
V_t=255;
I_a=(V_t-E_a)/R_a;
P_in=E_a*I_a;
disp(P_in,'electromagnetic power(W)');
T=P_in/w_m;
disp(T,'torque(Nm)');

disp('when terminal voltage is 248V');
V_t=248;
I_a=(E_a-V_t)/R_a;
P_in=E_a*I_a;
disp(P_in,'electromagnetic power(W)');
T=P_in/w_m;
disp(T,'torque(Nm)');
```

Scilab code Exa 7.9 to calculate electomagnetic power

```
//to calculate electomagnetic power

clc;
n_f=3000;          //field speed
n_a=2950;          //armature speed
```

```
E=250;
E_a=E*(n_a/n_f);
V_t=250;
R_a=0.05;
I_a=(V_t-E_a)/R_a;
P_in=V_t*I_a;
disp(P_in,'power(W)');
P=E_a*I_a;
disp(P,'electromagnetic power(W)');
```

Scilab code Exa 7.10 to calculate cross and demagnetising turns per pole

```
// to calculate cross and demagnetising turns/pole

clc;
P=250000;
V=400;
I_a=P/V;        //armature current
n=6;          //no of parallel path
I_c=I_a/n;     //conductor current
Z=720;         //lap wound conductors
AT_a=(1/2)*Z*I_c/n;

B=2.5*n/2;          //brush leadof 2.5 angular degrees
   (mech) from geo neutral
AT_c=AT_a*(1-(2*B)/180);
disp(AT_c,'cross magnetising ampere turns(AT/pole)')
   ;
AT_d=AT_a*((2*B)/180);
disp(AT_d,'demagnetising ampere turns(AT/pole)');
```

Scilab code Exa 7.11 to calculate no of conductors on each pole piece

```
//to calculate no of conductors on each pole piece

clc;
Z=256;
A=6;
P=6;
r=.71;         //ratio of pole arc to pole pitch
N_cw=(Z/(2*A*P))*r;
N_cc=ceil(2*N_cw);
disp(N_cc,'compensating conductors/pole');
```

Scilab code Exa 7.12 to calculate no of turns reqd on each interpole

```
//to calculate no of turns reqd on each interpole

clc;
P=25000;
V=440;
I_a=P/V;
Z=846;
A=2;
P=4;
B_i=.5;
u_o=4*%pi*10^-7;
l_gi=.003;
AT_i=((I_a*Z)/(2*A*P))+(B_i*l_gi)/u_o;
N_i=ceil(AT_i/I_a);
disp(N_i,'no of turns');
```

Scilab code Exa 7.13 to calculate mmf per pole and speed at no load in rpm

```
//to calculate mmf per pole and speed at no load(rpm)

clc;
ATppole=[1200 2400 3600 4800 6000];
V_i=[76 135 180 215 240];
plot(ATppole,V_i);
xlabel('AT/pole');
ylabel('E_a(V)');

V=240;
vd=25;          //voltage drop ie I_a*(R_a+R_se)
E_a=V-vd;
AT_netfl=4800;
AT_sefl=2400;
AT_sh=AT_sefl;

AT_senl=(3/25)*AT_sefl;
AT_sh=2400;          //no change
AT_netnl=AT_senl+AT_sh;
disp(AT_netnl,'mmf/pole on no load(AT)');
n=850;
E_a=148;          //from the magnetising curve
E_anl=240-3;
nnl=n*E_anl/E_a;
disp(nnl,'speed at no load(rpm)');
```

Scilab code Exa 7.14 to estimate at full load internal induced emf voltage drop caused y armature rxn and field current armature rxn demagnitisation

```
// to estimate at full load internal induced emf, voltage drop caused y armature rxn, and field current ~ armature rxn demagnitisation

clc;
```

```
I_f=[0 0.2 0.4 0.6 0.8 1 1.2 1.4];
Voc=[10 52 124 184 220 244 264 276];
plot(I_f,Voc);
xlabel('I_f(A)');
ylabel('Voc');

I_afl=50;
R_a=.3;
vd=I_afl*R_a;
V=240;
E_a=V+vd;
disp(E_a,'internal induced emf(V)');
V_oc=276;          //from magnetising curve,I_f=1.4
V_d=V_oc-E_a;
disp(V_d,'armature rxn vol drop(V)');
I_f=0.36;
K_ar=I_f/I_afl;
disp(K_ar,'armature rxn demagnetisation');
```

Scilab code Exa 7.16 to calculate terminal voltage and rated output current and calculate no of series turns per pole

```
//to calculate terminal voltage and rated output
   current and calculate no of series turns/pole

clc;
P=100000;
V=200;
I_L=P/V;
I_f=5;
I_a=I_L+I_f;
I_se=I_a;
N_se=5;
N_f=1200;
I_feq=I_f+(N_se/N_f)*I_se;
```

```
n=1000;
E_a=225;
nn=950;
E_aa=E_a*(nn/n);
R_a=0.03;
R_se=0.004;
V_t=E_aa-I_a*(R_a+R_se);
disp(V_t,'terminal voltage(V)');
I_fd=0.001875*I_a;
V_t=200;
E_a=V_t+I_a*(R_a+R_se);
E_aa=E_a*(n/nn);
I_fnet=7.5;
N_f=1000;
N_se=ceil((I_fnet+I_fd-I_f)*(N_f/I_a));
disp(N_se,'no of series turns/pole');
```

Scilab code Exa 7.21 to determine demagnetising AT per pole and no of series turns reqd

```
//to determine demagnetising AT/pole and no of
   series turns reqd

clc;
V_oc=[220 230 240 250 260 270];
I_f=[1 1.15 1.35 1.5 1.69 2.02];
plot(I_f,V_oc);
xlabel('I_f(A)');
ylabel('V_oc(V)');

V=240;
I_a=83.3;
R_a=.12;
E_a=V+I_a*R_a;
n=1150;
```

```
nn=1190;
Ea=E_a*(nn/n);
I_f=2.1;
I_fnet=1.65;
I_fd=I_f-I_fnet;
N_sf=550;          //shunt field turns/pole
AT_d=N_sf*I_fd;
disp(AT_d,'demagnetising AT_d/pole');

//at no load(1190rpm)
V_t=230;
I_f=1.43;
AT_f=N_sf*I_f;
R_f=V_t/I_f;

//at load(1150rpm)
I_L=I_a-(V/R_f);
V_a=(V+I_a*.045)/(1+(.045/R_f));
E_a=V_a+I_a*.12;
//consult mag field
Ea=E_a*(nn/n);
Ifn=1.675;      //needed
ATn=N_sf*Ifn;
If=V_a/R_f;
ATf=N_sf*If;

ATse=ATn+AT_d-AT_f;
I_L=I_a-If;
Nse=floor(ATse/I_L);
disp(Nse,'no of series turns/pole');
```

Scilab code Exa 7.22 to compute terminal voltage at rated voltage current

```
// to compute terminal voltage at rated voltage
```

```
    current

clc;
R_a=0.05;
R_se=.01;
N_f=1000;
N_se=3;
I_sf=5.6;          //shunt field current
I_L=200;
I_a=I_L+I_sf;
N=N_f*I_sf+I_a*N_se;          //excitation ampere
    turns
I_freq=N/N_f;

E_a=282;
n=1200;
nn=1150;
Ea=E_a*(nn/n);
V_t=Ea-I_a*(R_a+R_se);
disp(V_t,'terminal voltage(V)');
```

Scilab code Exa 7.23 to calculate no series turns

```
//to calculate no series turns

clc;
I_sf=5.6;
N_f=1000;
AT_f=I_sf*N_f;
I_a=205.6;
Z=400;
I_L=200;
AT_d=Z*(I_a/I_L);
V_t=250;
R_a=0.05;
```

```
R_se=.01;
E_a=V_t+I_a*(R_a+R_se);
n=1150;
nn=1200;
Ea=E_a*(nn/n);

I_fnet=6.2;
ATnet=I_fnet*N_f;

ATse=ATnet+AT_d-AT_f;
Nse=ceil(ATse/I_a);
disp(Nse,'no of series turns/pole');
```

Scilab code Exa 7.24 to find generator output

```
//to find generator output

clc;
P=20000;
V=250;
I_a=P/V;
R_a=.16;
vd=I_a*R_a;
function [P_o]=output(E_a)
    V_t=E_a-vd;
    P_o=I_a*V_t;
    disp(P_o,'generator output(W)');
endfunction
disp('at I_f=1A');
E_a=150;
P_o=output(E_a);
disp('at I_f=2A');
E_a=257.5;
P_o=output(E_a);
disp('at I_f=2.5A');
```

```
E_a=297.5;
P_o=output(E_a);

disp('at speed 1200rpm');
function [Ea]=ratio(E_a);
    Ea=.8*E_a
endfunction
disp('at I_f=1A');
E_a=150;
Ea=ratio(E_a);
P_o=output(Ea);
disp('at I_f=2A');
E_a=257.5;
Ea=ratio(E_a);
P_o=output(Ea);
disp('at I_f=2.5A');
E_a=297.5;
Ea=ratio(E_a);
P_o=output(Ea);
```

Scilab code Exa 7.25 to find power to the load

```
//to find power to the load

clc;
R_L=3;
R_a=.16;
function [P_o]=output(E_a)
    I_a=E_a/(R_a+R_L);
    P_o=I_a^2*R_L;
    disp(P_o,'power fed to the load(W)');
endfunction
disp('at I_f=1A');
E_a=150;
P_o=output(E_a);
```

```
disp('at I_f=2A');
E_a=257.5;
P_o=output(E_a);
disp('at I_f=2.5A');
E_a=297.5;
P_o=output(E_a);
```

Scilab code Exa 7.28 to compute the generator induced emf when fully loaded in long shunt compound and short shunt compound

```
//to compute the generator induced emf when fully
   loaded in long shunt compound and short shunt
   compound

clc;
P=75000;
V_t=250;
I_L=P/V_t;
R_a=.04;
R_se=.004;
R_f=100;
disp('case of long shunt');
I_f=V_t/R_f;
I_a=I_L+I_f;
V_b=2;
E_aLS=V_t+I_a*(R_a+R_se)+V_b;
disp(E_aLS,'generator induced emf(V)');

disp('case of short shunt');
V_b=V_t+I_L*R_se;
I_f=V_b/R_f;
I_a=I_L+I_f;
E_aSS=V_t+(I_a*R_a)+2;
disp(E_aSS,'generator induced emf(V)');

```

```
d=(E_aLS-E_aSS)*100/V_t;
disp(d,'percent diff');
```

Scilab code Exa 7.29 to find field current and field resistance at rated terminal voltage em power and torque

```
// to find field current and field resistance at rated terminal voltage, em power and     torque

clc;
V_o=250;        //no load voltage
I_f=1.5;
R_f=V_o/I_f;    disp(R_f,'field resistance(ohm)');
P=25000;
V_t=220;
I_L=P/V_t;
I_a=I_L;        disp(I_a,'field current(A)');
R_a=.1;
E_a=V_t+I_a*R_a;
I_f=1.1;
R_f=V_t/I_f;        disp(R_f,'field resistance(ohm)');
I_a=I_L-I_f;
emp=E_a*I_a;
disp(emp,'em power(W)');
n=1600;
emt=emp/(n*2*%pi/60);
disp(emt,'torque(Nm)');
I_fa=1.25;        //actual I_f
I_c=I_fa-I_f;
disp(I_c,'I_f needed to counter effect armature current');
```

Scilab code Exa 7.32 to determine the reduction of flux per pole due to armature rxn

```
//to determine the reduction of flux/pole due to
   armature rxn

clc;
V=250;
R_a=.7;
function [phi]=arxn(I_a,n)
    phi=(V-I_a*R_a)/n;
endfunction

phinl=arxn(1.6,1250);
disp(phinl,'flux/pole no load');

phil=arxn(40,1150);
disp(phil,'flux/pole load');

d=(phinl-phil)*100/phinl;
disp(d,'reduction in phi due to armature rxn(%)');
```

Scilab code Exa 7.33 to determine internal em torque developed

```
//to determine internal em torque developed

clc;
V=250;
I_a=85;
R_a=.18;
E_a=V-I_a*R_a;
n=1100;
T=E_a*I_a/(n*2*%pi/60);
disp(T,'torque(Nm)');
T_1=.8*T;     disp(T_1,'new torque(Nm)');
```

```
//T=K_a'*K_f*I_f*I_a=K_a'*K_f*.8*I_f*I_a1     so
I_a1=I_a/.8;
E_a1=V-I_a1*R_a;
//E_a=K_a'*K_f*I_f*n
//E_a1=K_a'*K_f*.8*I_f*n1     so
n1=(E_a1/E_a)*n/.8
disp(n1,'speed is(rpm)');
```

Scilab code Exa 7.34 to determine speed calculate internal torque developed on load and no load

```
//to determine speed, calculate internal torque
   developed on load and no load

clc;
V=220;
R_f=110;
I_f=V/R_f;
I_L=5;
I_a0=I_L-I_f;
R_a=.25;
E_a0=V-I_a0*R_a;
n=1200;
T_0=(E_a0*I_a0)/(2*%pi*n/60);
disp(T_0,'torque at no load(Nm)');

I_L=62;
I_a1=I_L-I_f;
E_a1=V-I_a1*R_a;
n1=(E_a1/E_a0)*n/.95;    disp(n1,'speed(rpm)');
T_1=(E_a1*I_a1)/(2*%pi*n1/60);
disp(T_1-T_0,'torque at on load(Nm)');
```

Scilab code Exa 7.36 to sketch speed the speed torque characteristicsof the series motor connectedto mains by calculating speed and torque values at diff values of armature current

```
//to sketch speed the speed-torque characteristicsof
    the series motor connectedto mains by
   calculating speed and torque values at diff
   values of armature current

clc;
Ise=[75 100 200 300 400];
V=250;
Ra=.08;
function [Ea]=Eaa(Ise)
Ea=V-Ra*Ise;
endfunction

Eav=[121.5 155 250 283 292];
n=1200;
function[nn]=speed(Ea,Eav)
nn=n*Ea/Eav;
    endfunction
function [T]=torque(nn,Ea,Ise)
    T=(60*Ea*Ise/(2*%pi*nn));
endfunction

Ise=75;
Ea=Eaa(Ise);
Eav=121.5;
nn1=speed(Ea,Eav);
T1=torque(nn1,Ea,Ise);

Ise=100;
Ea=Eaa(Ise);
Eav=155;
nn2=speed(Ea,Eav);
T2=torque(nn2,Ea,Ise);

```

```
Ise=200;
Ea=Eaa(Ise);
Eav=250;
nn3=speed(Ea,Eav);
T3=torque(nn3,Ea,Ise);

Ise=300;
Ea=Eaa(Ise);
Eav=283;
nn4=speed(Ea,Eav);
T4=torque(nn4,Ea,Ise);

Ise=400;
Ea=Eaa(Ise);
Eav=292;
nn5=speed(Ea,Eav);
T5=torque(nn5,Ea,Ise);

nn=[nn1 nn2 nn3 nn4 nn5];disp(nn,'speed(rpm)');
T=[T1 T2 T3 T4 T5];disp(T,'torque(Nm)');

plot(T,nn);
xlabel('T(Nm)');
ylabel('n(rpm)');
```

Scilab code Exa 7.37 to determine the power delivered to the fan torque developed by the motor and calculate external resistance to be added to armature ckt

```
//to determine the power delivered to the fan,torque
    developed by the motor and calculate external
   resistance to be added to armature ckt

clc;
V=220;
```

```
Ra=.6;
Rse=.4;
Ia=30;
Ea=V-(Ra+Rse)*Ia;
P=Ea*Ia;    disp(P,'Power(W)');
n=400;
w=2*%pi*n/60;
T=P/w;    disp(T,'torque(Nm)');

nn=200;
T1=T*(nn/n)^2;
Iaa=Ia*nn/n;
w1=2*%pi*nn/60;
P1=T1*w1;disp(P1,'power developed when n=200 rpm((W)
    )');
Ea1=P1/Iaa;
Rext=(V-Ea1)/Iaa-(Ra+Rse);disp(Rext,'external
    resistance(ohm)');
```

Scilab code Exa 7.38 to determine the starting torque developed

```
// to determine the starting torque developed
clc;
P=180000;
V=600;
Ia=P/V;
Ra=.105;
Ea=V-Ia*Ra;
n=600;
nn=500;
Eaa=Ea*nn/n;
Iaa=282;    //from magnetising curve
Iad=Ia-Iaa;
Ias=500;    //at start
k=Iad/Ia^2;
```

```
Iae=Ias-Iad*k;
Eas=590;      //from magnetising curve
Ts=Eas*Ias/(2*%pi*nn/60);disp(Ts,'T_start(Nm)');
```

Scilab code Exa 7.39 to determine speed and mech power

```
//to determine speed and mech power

clc;
k=.2*10^-3;
Ia=250;
Iad=k*Ia^2;
Ianet=Ia-Iad;
Ea=428;      //from magnetising curve
V=600;
Ra=.105;
Eaact=V-Ia*Ra;
n=500;
nn=n*Eaact/Ea;disp(nn,'speed(rpm)');
Pmech=Eaact*Ia;disp(Pmech,'mech power debeloped(W)')
   ;
T=Pmech/(2*%pi*nn/60);disp(T,'torque(Nm)');
```

Scilab code Exa 7.40 to calculate the mmf per pole on no load and speed developed

```
//to calculate the mmf per pole on no load and speed
    developed

clc;
ATsefl=2400;
ATsenl=(3/25)*ATsefl;
ATsh=ATsefl;
```

```
ATnet=ATsenl+ATsh;disp(ATnet,'mmf/pole(AT)');
Ea=148;     //from magnetising curve
V=240;
vd=3;
Eanl=V-vd;
n=850;
nnl=n*Eanl/Ea;
disp(nnl,'speed(rpm)');
```

Scilab code Exa 7.41 to calculate demagnetisising ampeare turns em torque starting torque and no of turns of the series field

```
//to calculate demagnetisising ampeare turns, em
   torque,starting torque and no of turns of the
   series field

clc;
P=10000;
Vt=240;
Ia=P/Vt;
If=.6;
Ra=.18;
Ri=0.025;
Ea=Vt-Ia*(Ra+Ri);
n=1218;
Eaa=Ea*Vt/Ea;
Iff=.548;    //from n-If characteristics
Ifd=If-Iff;
N_s=2000;    //shunt field turns
ATd=N_s*Ifd;    disp(ATd,'demagnetising ampere turns
   ');
T=Ea*Ia/(2*%pi*n/60);disp(T,'torque(Nm)');
Rf=320;
If=Vt/Rf;
ATd=165;    //given
```

```
Ifd=ATd/N_s;
Ifnet=If-Ifd;
n=1150;     //from n-If characteristics
//Ea=Ka*phi*w;     Ka*phi=k
k=Vt/(2*%pi*n/60);
Iastart=75;
Tstart=Iastart*k;disp(Tstart,'starting torque(Nm)');
n_0=1250;
Ea=240;
If=.56;     //from n-If characteristics
n=1200;
Rse=.04;
R=Rse+Ra+Ri;
Eaa=Ea-Ia*R;
nn=n*Ea/Eaa;
Ifnet=.684;     //from n-If characteristics
Ifd=Ifnet-If;
Nse=N_s*Ifd/Ia;     disp(ceil(Nse),'no of turns of
   the series field');
```

Scilab code Exa 7.42 to determine shunt field current of the motor demagnetising effect of armature rxn determine series field turns per pole speed of motor

```
//to determine shunt field current of the motor,
   demagnetising effect of armature rxn, determine
   series field turns/pole,speed of motor.

clc;
Voc=[180 200 220 240 250];
If=[1.18 1.4 1.8 2.4 2.84];
plot(If,Voc);
xlabel('If(A)');
ylabel('Voc(V)');
n_0=1350;     //at no load
```

```
Vt=230;
Ea=Vt;     //no voltage drop
If=1.08;     //from occ characteristic
disp(If,'If(A)');
n=1350;
Ia=56.5;
R=.15;
Ea=Vt-Ia*R;
Ifnet=1.8;     //from occ characteristic
Ifact=2.08;
Ifd=Ifact-Ifnet;
N_s=1200;     //shunt field turns
ATd=N_s*Ifd;     disp(ATd,'ATd');

Rf=.033;
Ea=Vt-Ia*(R+Rf);
n=1230;
nn=1350;
Eaa=Ea*nn/n;
Ifnet=2.41;ATnet=Ifnet*N_s;
If=1.08;
ATsh=If*N_s;
ATse=ATnet-ATsh+ATd;
Nse=ATse/Ia;     disp(floor(Nse),'series field turns'
   );
Nse=25;
ATse=Nse*Ia;
ATnet=ATsh-ATd+ATse;
Ifnet=ATnet/N_s;
Rs=.025;
Eaa=226;     //from occ
Eact=Vt-Ia*(R+Rs);
n=nn*Eact/Eaa;     disp(n,'speed(rpm)');
```

Scilab code Exa 7.43 to find the no of starter sections reqd and resistance of each section

```
//to find the no of starter sections reqd ,and
   resistance of each section

clc;
I1=55;
I2=35;
g=I1/I2;
V1=220;
R1=V1/I1;
Ra=.4;
n=log((R1/Ra)-g)+1;
disp((n),'no of starter sections reqd');

function [R]=res (re)
    R=(1/g)*re;
endfunction
R_1=R1-res(R1);disp(R_1,'R1(ohm)');
R_2=res(R_1);disp(R_2,'R2(ohm)');
```

Scilab code Exa 7.44 to find the lower current limit motor speed at each stud

```
//to find the lower current limit , motor speed at
   each stud

clc;
Pop=25*1000;
Vt=230;
Ra=.12;
rf=120;
Nfl=2000;
Iafl=Pop/Vt;
```

```
Iamax=1.5*Iafl;
k=5;
I1=Iamax;
R1=Vt/I1;
r=(R1/Ra)^(1/(k-1));
I2=I1/r;
function [R]=res (re)
    R=(1/r)*re;
endfunction
R_1=R1-res(R1);disp(R_1,'R1(ohm)');
R_2=res(R_1);disp(R_2,'R2(ohm)');
R_3=res(R_2);disp(R_3,'R3(ohm)');
R_4=res(R_3);disp(R_4,'R4(ohm)');

Iaf1=103.7;
Ea=Vt-Iaf1*Ra;
Ka=Ea/Nfl;
function [n]=speed(r)
    Ea=Vt-I2*r;
    n=Ea/Ka;
endfunction
r1=R1;
n1=speed(r1);disp(n1,'n1(rpm)');
r2=r1-R_1;
n2=speed(r2);disp(n2,'n2(rpm)');
r3=r2-R_2;
n3=speed(r3);disp(n3,'n3(rpm)');
r4=r3-R_3;
n4=speed(r4);disp(n4,'n4(rpm)');
```

Scilab code Exa 7.45 to calculate the ratio of full load speed to no load speed

```
//to calculate the ratio of full load speed to no
   load speed
```

```
clc;
V=400;
Rf=200;
If=V/Rf;
Inl=5.6;
I_a0=Inl-If;
vd=2;     //voltage drop
Ra=.18;
E_a0=V-Ra*I_a0-vd;
Ifl=68.3;
Iafl=Ifl-If;
E_afl=V-Ra*Iafl-vd;
e=.03;     //armature rxn weakens the field by 3%
k=(E_afl/E_a0)*(1/(1-e));
disp(k,'n_fl/n_nl');
```

Scilab code Exa 7.46 to calculate load torque motor speed and line current

```
//to calculate load torque, motor speed and line
   current

clc;
V=250;
Rf=41.67;
If1=V/Rf;
Ia=126;
Ia1=Ia-If1;
Ra=.03;
Ea1=V-Ra*Ia1;
n1=1105;     //rpm
w1=2*%pi*n1/60;
Ka=Ea1/(If1*w1);
T=Ka*If1*Ia1;
```

```
disp(T,'torque(Nm)');

If2=5;
Ia2=Ia1*(If1/If2);
I_L2=Ia2+2;disp(I_L2,'motor current(A) initial');
Ea2=V-Ra*Ia2;
w2=Ea2/(Ka*If2);

If1=6;
Voc1=267;
n=1200;
k1=Voc1/(2*%pi*n/60);     //k=Ka*phi
If1=5;
Voc2=250;
n=1200;
k2=Voc2/(2*%pi*n/60);     //k=Ka*phi
Ia2=Ia1*(k1/k2);
I_L2=Ia2+2;disp(I_L2,'motor current(A) final');
Ea2=V-Ra*Ia2;
w2=Ea2/k2;
disp(w2,'motor speed(rad/s)');
```

Scilab code Exa 7.47 to calculate armature current speed and value of external resistance in field ckt

```
//to calculate armature current,speed and value of
   external resistance in field ckt

clc;
V=250;
Ia=5;
Ra=.6;
n=1000;
k=(V-Ia*Ra)/(2*%pi*n/60);
T=100;
```

```
Ia=T/k;disp(Ia,'armature current(A)');
w_m=(V-Ia*Ra)/k;
n=(60*w_m)/(2*%pi);disp(n,'speed(rpm)');

Rf=150;
If=V/Rf;
kk=k/If;
Iaa=44.8;
nn=1200;
Iff=(V-Iaa*Ra)/(kk*2*%pi*nn/60);
Rftot=V/Iff;
Rfext=Rftot-Rf;
disp(Rfext,'external resistance(ohm)');
```

Scilab code Exa 7.48 to determine speed and torque of the motor

```
//to determine speed and torque of the motor

clc;
Ra=0.035;
Rf=0.015;
V=220;
I=200;
Ea=V-I*(Ra+Rf);
disp('full field winding');
n=900;
nn=n*Ea/V;disp(nn,'speed(rpm)');
T=(Ea*I/2)/(2*%pi*nn/60);disp(T,'torque(Nm)');
disp('field winding reduced to half');
Rse=Rf/2;
Rtot=Rse+Ra;
Ea=V-I*(Rtot);
Iff=I/2;
V=150;    //from magnetisation characteristic
nn=n*Ea/V;disp(nn,'speed(rpm)');
```

```
T=(Ea*I)/(2*%pi*nn/60);disp(T,'torque(Nm)');

disp('divertor across series field');
Ra=0.03;
Rse=.015;
Kd=1/((Rse/Ra)+1);
Ise=Kd*I;
V1=192;
I1=150;
V2=150;
I2=100;
v=V2+((V1-V2)/(I1-I2))*(Ise-I2);
R=(2/3)*Rse;
Ea=V-I*(Ra+R);
nn=n*Ea/v;disp(nn,'speed(rpm)');
T=(Ea*I)/(2*%pi*nn/60);disp(T,'torque(Nm)');
```

Scilab code Exa 7.50 to determine speed regulation load speed and power regulation and compare power wasted in both cases

```
//to determine speed regulation , load speed and
   power regulation and compare power wasted in both
    cases

clc;
V=230;
Ra=2;
Ia=5;
Ea=V-Ia*Ra;
n=1250;
w=2*%pi*n/60;
k=Ea/w;     //k=Ka*phi
Re=15;
Ia0=1;
Ea=V-Ia0*(Ra+Re);
```

```
w0=Ea/k;
Ia=5;
Ea=V-Ia*(Ra+Re);
w=Ea/k;
wr=(w0-w)*100/w;
disp(wr,'(i)speed regulation(%)');

R1=10;
R2=15;
B=R2/(R1+R2);
V_TH=V*B;
R_TH=R1*B;
Ea=V_TH-Ia0*(R_TH+Ra);
w0=Ea/k;
Ia=5;
Ea=V_TH-Ia*(R_TH+Ra);
w=Ea/k;
wr=(w0-w)*100/w;
disp(wr,'(ii)speed regulation(%)');

Pe=Ia^2*Re;
disp(Pe,'power loss by rheostat control(W)');
Ra=2;
Ea=98;
Va=Ea+Ra*Ia;
P2=Va^2/R2;
I2=Va/R2;
I1=I2+Ia;
P1=I1^2*R1;
Pe=P1+P2;
disp(Pe,'power loss by shunted armature control(W)')
    ;
```

Scilab code Exa 7.52 to determine armature current

```
//to determine armature current

clc;
n1=1600;
Ia1=120;
n2=400;
Ia2=(n1*Ia1)/n2;      //P=K*Ia*n
disp(Ia2,'Ia(A)');
```

Scilab code Exa 7.54 to find speed and ratio of mech op

```
//to find speed and ratio of mech o/p

clc;
V=400;
Ra=.25;
Ia1=25;
Ea1=V-Ra*Ia1;
n1=1200;
Rr=2.75;
Ia2=15;
Ea2=V-(Ra+Rr)*Ia2;
phi=.7;     //phi=(phi(15)/phi(25))
n2=(Ea2/Ea1)*n1/phi;
disp(n2,'speed(rpm)');

Po2=Ea2*I2;
Po1=Ea1*I1;
disp(Po2/Po1,'ratio of mech o/p');
Ia=120;     //Ia is constant indep of speed
disp(Ia,'Ia(A)');
```

Scilab code Exa 7.55 to calculate the armature voltage reqd

```
//to calculate the armature voltage reqd

clc;
V=500;
Ra=.28;
Ia1=128;
Ea1=V-Ia1*Ra;
//(Vt2-.28*Ia2)-->n1/sqrt(2)      (i)
//Ea1-->n1     (ii)
Vt2=(Ea1/sqrt(2))+(Ia1*Ra);
disp(Vt2,'armature voltage(V)');
```

Scilab code Exa 7.56 to find the range of generator field current motor current and speed

```
//to find the range of generator field current,motor
    current and speed

clc;
If=[0 0.2 0.3 0.4 0.5 0.6 0.7 0.8 1 1.2];
Voc=[45 110 148 175 195 212 223 230 241 251];
plot(If,Voc);
xlabel('If(A)');
ylabel('Voc(V)');
Ifm=0.8;
Eam2=230;      //at 1500rpm
n_m2=1500;
Ra=.5;
//n_m=300-1500rpm(range)
n_m1=300;
Eam1=Eam2*n_m1/n_m2;
P_mot=4500;
Ia1=P_mot/Eam1;
Eag1=Eam1+2*Ra*Ia1;
If1=.3-((.1/(148-110))*(148-Eag1));
```

```
disp(If1,'lower limit of current(A)');

n_m2=1500;
Eam2=230;
P_mot=4500;
Ia2=P_mot/Eam2;
Eag2=Eam2+2*Ra*Ia2;
If2=1.2-(.2/(241-230)*(251-Eag2));
disp(If2,'upper limit of current(A)');

Ifg=1;
Eag=241;
n=1500;
Pop=4500;
//((241-Eam)/(2*.5))*Eam=4500
//after solving
//Eam^2-241*Eam+4500=0
function [x]=quad(a,b,c)
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
    if(x1<x2)
        x=x2;
    else
        x=x1;
    end
endfunction
Eam=quad(1,-241,4500);
Ifm=.2;
Eamm=110;
n_m=n*Eam/Eamm;disp(n_m,'speed(rpm)');
Ia=(Eag-Eam)/(2*.5);disp(Ia,'motor current(A)');
```

Scilab code Exa 7.57 to calculate mc eff as a generator and max eff when generating and motoring

```
//to calculate m/c eff as a generator and max eff
   when generating and motoring.

clc;
Pop=10*1000;
Vt=250;
Ra=.8;
Rf=275;
Ia=3.91;
Psh=Vt^2/Rf;
Prot=Vt*Ia-Ia^2*Ra;disp(Prot,'rotational loss(W)');

I1=Pop/Vt;
If=Vt/Rf;
Ia=I1+If;
Ploss=Prot+Psh+Ia^2*Ra;
Eff_gen=(1-Ploss/(Ploss+Pop))*100;disp(Eff_gen,'
   generator eff(%)');

Ia=I1-If;
Ploss=Prot+Psh+Ia^2*Ra;
Eff_motor=(1-Ploss/(Pop))*100;disp(Eff_motor,'motor
   eff(%)');

Ia=sqrt((Prot+Psh)/Ra);
Ploss_tot=2*(Prot+Psh);disp(Ploss_tot,'total loss(W)
   ');

I1=Ia-If;
Pout=Vt*I1;
Eff_gen_max=((1-Ploss_tot/(Ploss_tot+Pout)))*100;
disp(Eff_gen_max,'max generator eff(%)');

I1=Ia+If;
Pin=Vt*I1;
Eff_motor_max=((1-Ploss_tot/(Pin)))*100;disp(
   Eff_motor_max,'max motor eff(%)');
```

Scilab code Exa 7.59 to determine rotational loss no load armature current and speed and also find speed regulation and to calculate armature current for given em torque

```
//to determine rotational loss, no load armature current and speed and also find speed regulation and to calculate armature current for given em torque

clc;
Pout=60*1000;
eff=.85;
P_L=((1/eff)-1)*Pout;
Pin=Pout+P_L;
V=600;
I_L=Pin/V;
Rf=100;
If=V/Rf;
Ia=I_L-If;
Ra=.16;
Ea=V-Ia*Ra;
n=900;
Prot=P_L-Ia^2*Ra-V*If;disp(Prot,'rotational loss(W)');

Iao=Prot/V;disp(Iao,'no load armature current(A)');
Eao=V;
n0=n*Eao/Ea;disp(n0,'no load speed(rpm)');
reg=(n0-n)*100/n;disp(reg,'speed regulation(%)');

K=Ea/(2*%pi*n/60);      //K=Ka*phi
T=600;
Ia=T/K;disp(Ia,'reqd armature current(A)');
```

Scilab code Exa 7.60 to determine load torque and motor eff armature current for max motor eff and ots value

```
//to determine load torque and motor eff,armature
   current for max motor eff and ots value

clc;
V=250;
Ia=35;
Ra=.5;
Ea=V-Ia*Ra;
Poutg=Ea*Ia;
Prot=500;
Pout_net=Poutg-Prot;
n=1250;
w=2*%pi*n/60;
T_L=Pout_net/w;disp(T_L,'load torque(Nm)');

Rf=250;
If=V/Rf;
I_L=If+Ia;
Pin=I_L*V;
eff=Pout_net*100/Pin;disp(eff,'efficiency(%)');

Pk=Prot+V*If;
Ia=sqrt(Pk/Ra);disp(Ia,'armature current(A)');
Tloss=2*Pk;
I_L=If+Ia;
Pin=I_L*V;
eff_max=1-(Tloss/Pin);disp(eff_max*100,'max
   efficiency(%)');

Ea1=V-Ia*Ra;
n1=n*Ea1/Ea;disp(n1,'speed(rpm)');
```

```
w=2*%pi*n1/60;
Poutg=Ea1*Ia;
Pout_net=Poutg-Prot;
T_L=Pout_net/w;disp(T_L,'load torque(Nm)');
```

Scilab code Exa 7.61 to calculate rotational loss armature resistance eff line current and speed

```
//to calculate rotational loss ,armature resistance ,
   eff ,line current and speed

clc;
Pshaft=20000;
eff=.89;
P_L=((1/eff)-1)*Pshaft;
Pin=Pshaft+P_L;
V=250;
I_L=Pin/V;disp(I_L,'line current(A)');
Rf=125;
If=V/Rf;
Ia=I_L-If;

Ploss=P_L/2;
Ra=Ploss/Ia^2;disp(Ra,'armature resistance(ohm)');
Psh=V*If;
Prot=Ploss-Psh;disp(Prot,'rotational loss(W)');
Ea=V-I_L*Ra;
n=850;
Ia=100;

Pc=Ia^2*Ra;
P_L=Pc+Ploss;
Pin=V*I_L;
eff=(1-P_L/Pin)*100;
Ea1=V-Ia*Ra;
```

```
n1=n*Ea1/Ea;disp(n1,'speed(rpm)');
```

Scilab code Exa 7.62 to calculate eff of motor and generator

```
//to calculate eff of motor and generator

clc;
Iag=60;
Ia=15;
Iam=Iag+Ia;
Vt=250;
Ram=.2;
Rag=.2;
Pstray=.5*(Vt*Ia-Iam^2*Ram-Iag^2*Rag);
Ifm=2;
Pinm=Vt*(Iam+Ifm);
P_Lm=(Pstray+Vt*Ifm)+Iam^2*Ram;
eff_M=1-(P_Lm/Pinm);disp(eff_M*100,'efficiency of
    motor(%)');

Iag=60;
Ifg=2.5;
P_Lg=(Pstray+Vt*Ifg)+Iag^2*Rag;
Poutg=Vt*Iag;
eff_G=1-(P_Lg/(Poutg+P_Lg));disp(eff_G*100,'
    efficiency of generator(%)');
```

Scilab code Exa 7.63 to calculate torque constt value of rotational loss stalled torque and stalled current of motor armature current anad eff motor op and eff

```
//to calculaate torque constt,value of rotational loss,stalled torque and stalled current of motor, armature current anad eff, motor o/p and eff

clc;
Vt=6;
Iao=.0145;
n=12125;
w=2*%pi*n/60;
Ra=4.2;
Ea=Vt-Iao*Ra;
Km=Ea/w;disp(Km,'torque constt');

Prot=Ea*Iao;disp(Prot,'rotational loss(W)');

Ia_stall=Vt/Ra;disp(Ia_stall,'stalled current(A)');
Tstall=Km*Ia_stall;disp(Tstall,'stalled torque(Nm)');

Poutg=1.6;
function [x]=quad(a,b,c)
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
    if(x1>x2)
        x=x2;
    else
        x=x1;
    end
endfunction
//Ea*Ia=1.6;
//(Vt-Ra*Ia)*Ia=Poutg;
Ia=quad(Ra,-Vt,Poutg);
Ea=Vt-Ia*Ra;
wo=Ea/Km;
Proto=Prot*(w/wo)^2;
Pout_net=Poutg-Prot;
Pi=Vt*Ia;
```

```
eff=Pout_net/Pi;disp(eff*100,'efficiency(%)');

n1=10250;
w1=2*%pi*n1/60;
Km=.004513;
Ea1=Km*w1;
Ia=(Vt-Ea1)/Ra;
Pout_gross=Ea1*Ia;
Prot1=Prot*(n1/n);
Pout_net=Pout_gross-Prot1;disp(Pout_net,'o/p power(W)');
Pin=Vt*Ia;
eff=Pout_net/Pin;disp(eff*100,'efficiency(%)');
```

Chapter 8

Synchronous Machines

Scilab code Exa 8.2 to determine voltage regulation by mmf method

```
//to determine voltage regulation by mmf method

clc;
pf=0.85;
P=150*10^6;
V=13*1000;
Iarated=P/(sqrt(3)*pf*V);
If=750;
Ifocc=810;
B=acosd(pf);
Ff=sqrt((Ifocc+If*sind(B))^2+(If*cosd(B))^2);
Ef=16.3*1000;
vr=Ef/V-1;
disp(vr*100,'voltage regulation(%)');
```

Scilab code Exa 8.3 to calculate syn chronous reactance leakage reactance voltage regulation

```
//to calculate syn chronous reactance ,leakage reactance ,voltage regulation

clc;
If=[50 75 100 125 150 162.5 200 250 300];
Voc=[6.2 8.7 10.5 11.6 12.8 13.7 14.2 15.2 15.9];
plot(If,Voc);
xlabel('If(A)');
ylabel('Voc(V)');

r=10*10^6;      //rating
V=13000;
Ia=r/(sqrt(3)*V);
I_SC=688;     //corresponding to V
Xs=V/(sqrt(3)*I_SC);disp(Xs,'sync reactance(ohm)');
V_a=1200;
Xl=V_a/(sqrt(3)*Ia);disp(Xl,'leakage reactance(ohm)');
Ifar=90;
Er=complex(V,sqrt(3)*Ia*Xl);
If=185;     //corresponding to Er
Iff=sqrt((If+Ifar*sind(40.5))^2+(Ifar*cosd(40.5))^2);
Eff=15200;      //corresponding to Iff
vr=(Eff/V-1)*100;disp(vr,'voltage regulation(%)');

Xsadj=Xs*complex(.8,-.6);j=sqrt(-1);
Ef=(V+sqrt(3)*Ia*Xsadj);
If=(150/13)*abs(Ef);
Vtoc=14800;     //corresponding to If
vr=(Vtoc/V-1)*100;disp(vr,'voltage regulation(%)');
```

Scilab code Exa 8.6 to calculate the excitation emf

```
//to calculate the excitation emf
```

```
clc;
Vt=3300;
Xs=18/3;
pf=.707;
P=800*1000;
Ia=P/(sqrt(3)*Vt*pf);
a=Ia*Xs/sqrt(2);
b=Vt/sqrt(3);
Ef=sqrt((a+b)^2+a^2)*sqrt(3);
disp(Ef,'excitation emf(V)(line)');
```

Scilab code Exa 8.7 to compute the max power and torque terminal voltage

```
//to compute the max power and torque,terminal
   voltage

clc;
V=3300;
Vt=V/sqrt(3);
P=1000*10^3;
pf=1;
Ia=P/(V*sqrt(3)*pf);
Xsm=3.24;
j=sqrt(-1);
Efm=Vt-j*Ia*Xsm;
Efg=abs(Efm);
P_emax=3*Vt*Efg/Xsm;disp(P_emax,'max power(W)');
p=24;
f=50;
w_sm=(120*f*2*%pi)/(p*60);
Tmax=P_emax/w_sm;disp(Tmax,'torque(Nm)');

Xsg=4.55;
```

```
Efm=Vt-j*Ia*Xsg;
Efmm=abs(Efm);
X=Xsm+Xsg;
P_emax=3*Efg*Efmm/X;disp(P_emax,'max power(W)');
Tmax=P_emax/w_sm;disp(Tmax,'torque(Nm)');

d=90;
Efm=Efg*complex(cosd(0),sind(0));
Efg=Efmm*complex(cosd(d),sind(d));
Ia=(Efg-Efm)/(j*X);
v=j*Ia*Xsm;
Vt=Efm+j*Ia*Xsm;
disp(abs(Vt)*sqrt(3),'line voltage(V)');
```

Scilab code Exa 8.8 max power supplied power angle d corresponding field current

```
//max power supplied, power angle d, corresponding
    field current

clc;
j=sqrt(-1);
r=100*10^6;      //va
V=11000;
P=100*10^6;
Ef=1;      //pu
Vth=1;      //pu
Xs=1.3;      //pu
Xth=.24;      //pu
P_emax=Ef*Vth/(Xs+Xth);disp(P_emax,'max power
    delivered(pu)');

Pe=1;
Vt=1;
d=asind(Pe*Xth/(Vt*Vth));disp(d,'power angle');
```

```
Vt=exp(j*d);
Ia=(Vt-Vth)/(j*Xth);
Ef=Vth+j*(Xs+Xth)*Ia;
Voc=11000;
If=256;
Ff=19150;
Iff=If*Ff/Voc;
disp(Iff,'If(A)');

Pe=0:0.01:0.8;
Vt=1+(0.24/1.54)*(1.54*Pe-1);
plot(Pe,Vt);
xlabel('load');
ylabel('Vt(V)');

Pe=0:0.01:0.8;
dl=asind(0.24*Pe);
Ef=1+(1.54/.24)*(exp(j*dl)-1);
If=(256/11)*Ef;
plot(Pe,abs(If));
xlabel('load');
ylabel('excittion current');
```

Scilab code Exa 8.9 to calculate the generator current and its pf

```
//to calculate the generator current and its pf

clc;
j=sqrt(-1);
X=.24;
r=400;      //rating in MVA
rr=600;      //rating in MVA
Pe=r/rr;
Vt=1;
Vth=1;
```

```
dl=asind(Pe*X/(Vt*Vth));
Ia=2*sind(dl/2)/X;
V=24000;
IaB=(rr/3)*10^6/(V/sqrt(3));
Iaa=Ia*IaB;disp(Iaa,'generating current(A)');
phi=dl/2;
pf= cosd(phi);disp(pf,'power factor');

Pe=1;
dl1=asind(Pe*X/(Vt*Vth));
Ia=2*sind(dl1/2)/X;
Iaa=Ia*IaB;disp(Iaa,'generating current(A)');
phi=dl1/2;
pf= cosd(phi);disp(pf,'power factor');
Ef=Vt+j*Ia*(complex(cosd(-phi),sind(-phi)))*X;
Eff=abs(Ef)*V;
dl2=atand(imag(Ef)/real(Ef));

Xth=.24;
Pe=abs(Ef)*Vth*sind(dl1+dl2)/(X+Xth);disp(Pe,'Pe(pu)');
```

Scilab code Exa 8.10 to calculate armature resistance sync reactance full load stray load loss Rac Rdc various categories of losses at full load full load eff

```
//to calculate armature resistance, sync reactance, full load stray load loss, Rac/Rdc,various categories of losses at full load,full load eff

clc;
r=60*10^3;
Psc=3950;
Isc=108;
Raeff=Psc/(3*Isc^2);disp(Raeff,'effective armature
```

```
resistance(ohm)');
V=400;
Ifoc=2.85;
Ifsc=1.21;
I_SC=Isc*Ifoc/Ifsc;
Zs=(V/sqrt(3))/I_SC;
Xs=sqrt(Zs^2-Raeff^2);disp(Xs,'sync reactance(ohm)');

t1=25;
t2=75;
Rdc=0.075;
Radc=Rdc*((273+t2)/(273+t1));
Iarated=r/(sqrt(3)*V);
Pscc=Psc*(Iarated/Isc)^2;
P=3*Iarated^2*Radc;disp(P,'armature loss(W)');
loss=Pscc-P;disp(loss,'loss(W)');

a=Raeff/Radc;disp(a,'Rac/Rdc');

Pwf=900;disp(Pwf,'windage and friction loss(W)');
tloss=2440;
closs=tloss-Pwf;disp(closs,'core loss(W)');
If=3.1;
Rf=110;
Pcu=If^2*Rf;disp(Pcu,'field cu loss(W)');
disp(loss,'stray load loss(W)');
b=loss+Pcu+closs+Pwf+P;
disp(b,'total loss(W)');

pf=0.8;
op=r*pf;
ip=op+b;
eff=op/ip;
disp(eff,'efficiency');
```

Scilab code Exa 8.11 to calculate net power op eff line current and pf

```
//to calculate net power op,eff,line current and pf

clc;
j=sqrt(-1);
Zs=(1/3)*(.3+j*6);
phi=atand(imag(Zs)/real(Zs));
Vt=400/sqrt(3);
Ef=600/sqrt(3);
a=sqrt(Vt^2+Ef^2-2*Vt*Ef*cosd(phi));
Ia=a/abs(Zs);disp(Ia,'line current(A)');
B=acosd((Vt^2+a^2-Ef^2)/(2*Vt*a));

phi=90-(90-atand(imag(Zs)/real(Zs)))-B;disp(cosd(phi),'pf');
Pein=Vt*Ia*cosd(phi);
Ra=.1;
b=Ia^2*Ra;
loss=2400;
Pmout=Pein-loss/3-b;disp(Pmout,'net power op(W)');
eff=Pmout/Pein;
disp(eff*100,'efficiency(%)');
```

Scilab code Exa 8.12 to find pf

```
//to find pf

clc;
j=sqrt(-1);
Zs=.8+j*5;
Vt=3300/sqrt(3);
```

```
Pein=800*10^3/3;     //per ph
pf=.8;
Qe=-Pein*tand(acosd(pf));
//a=Ef*sind(dl-a);
//b=Ef=cosd(dl-a);
a=((abs(Zs)/Vt)*(Pein-real(Zs)*(Vt/abs(Zs))^2));
b=((abs(Zs)/Vt)*(-Qe+imag(Zs)*(Vt/abs(Zs))^2));

Ef=sqrt(a^2+b^2);

Pein=(1200/3)*1000;
a=asind((abs(Zs)/(Vt*Ef))*(Pein-pf*(Vt/abs(Zs))^2));
Qe=imag(Zs)*(Vt/abs(Zs))^2-Ef*Vt*cosd(a)/abs(Zs);
pf=cosd(atand(Qe/Pein));
disp(pf,'pf');
```

Scilab code Exa 8.13 to determine excitation emf torque angle stator current pf max power kVAR delivered

```
//to determine excitation emf, torque angle,stator
   current , pf, max power, kVAR delivered

clc;
j=sqrt(-1);
P=10000;
V=400;
Ia=P/(sqrt(3)*V);
pf=.8;
phi=acosd(pf);
Iaa=Ia*complex(cosd(-phi),sind(-phi));
Vt=V/sqrt(3);
X=16;
Ef=Vt+j*X*Iaa;
disp(abs(Ef),'excitation emf(V)');
dl=atand(imag(Ef)/real(Ef));
```

```
disp(dl,'torque angle');

Pe=P*pf;
Eff=abs(Ef)*1.2;
dl=(Pe/3)*X/(Eff*Vt);
ta=asind(dl);
disp(ta,'torque angle');
Ia=(Eff*complex(cosd(ta),sind(ta))-Vt)/(j*X);
disp(abs(Ia),'stator current(A)');
disp(cosd(-atand(imag(Ia)/real(Ia))),'pf');

Ef=413;
Pemax=Ef*Vt/X;
Ia=(Ef*complex(cosd(90),sind(90))-Vt)/(j*X);
disp(abs(Ia),'stator current(A)');
disp(cosd(-atand(imag(Ia)/real(Ia))),'pf');

Qe=(imag(Ia)/real(Ia))*Pe;disp(Qe,'kVar delivered');
```

Scilab code Exa 8.14 to calculate armature current pf power angle power shaft torques kVar

```
//to calculate armature current, pf ,power angle,
    power , shaft torques ,kVar

clc;
j=sqrt(-1);
P=8000;
Prot=500;
Pmg=P+Prot;
Pein=Pmg;
Ef=750/sqrt(3);
Vt=231;
Xs=16;
dl=asind(Xs*(Pein/3)/(Ef*Vt));
```

```
Eff=Ef*complex(cosd(-dl),sind(-dl));
Ia=(Vt-Eff)/(j*Xs);
disp(abs(Ia),'armature current(A)');
disp(cosd(atand(imag(Ia)/real(Ia))),'pf');
f=50;
p=4;
n_s=120*f/p;
w_s=2*%pi*n_s/60;
T=Pein/w_s;disp(T,'torque developed(Nm)');
T_s=P/w_s;disp(T_s,'shaft torques(Nm)');

Ef=600/sqrt(3);
Ia=(Vt-Ef)/(j*Xs);
rr=3*Vt*Ia/1000;
disp(rr,'kVar rating');
c=(abs(Ia)/Vt)/(2*%pi*f);
disp(-c,'capicator rating(F)');

Ef=300/sqrt(3);
Ia=(Vt-Ef)/(j*Xs);
rr=3*Vt*Ia/1000;
disp(-rr,'kVar rating');
L=(Vt/abs(rr))/(2*%pi*f);
disp(L,'inductor rating(H)');

Ia=j*2000/Vt;
Ef=Vt-j*Ia*Xs;
disp(abs(Ef)*sqrt(3),'excitation(V)');
```

Scilab code Exa 8.15 find the excitation emf mech power developed pf

```
//find the excitation emf,mech power developed,pf

clc;
j=sqrt(-1);
```

```
V=6600;
Vt=V/sqrt(3);
r=4*10^6;
Ia=r/(sqrt(3)*V);
Xs=4.8;
//Vt^2+Ef^2-2*Vt*Efcosd(dl)=(Ia*Xs)^2
//after solving
//Ef^2-7.16*Ef+11.69=0;
function [x1,x2]=quad(a,b,c)
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
endfunction
[Ef1 Ef2]=quad(1,-7.16,11.69);
dl=20;
disp(Ef1,'excitation(kV)');
Pm=3*3.81*Ef1*sind(dl)/Xs;disp(Pm,'power developed(MW)');
pf1=Pm*10^6/(sqrt(3)*V*Ia);disp(pf1,'pf1');

disp(Ef2,'excitation(kV)');
Pm=3*3.81*Ef2*sind(dl)/Xs;disp(Pm,'power developed(MW)');
pf2=Pm*10^6/(sqrt(3)*V*Ia);disp(pf2,'pf2');
```

Scilab code Exa 8.16 to find power angle field current

```
//to find power angle,field current

clc;
j=sqrt(-1);
V=400;
Vt=V/sqrt(3);
pf=1;
Ia=50;
```

```
Xs=1.3;
Ef=Vt-j*Ia*Xs;
disp(-atand(imag(Ef)/real(Ef)),'power angle');

Pm=Vt*Ia*pf;
pff=.8;
Ia=Pm/(Vt*pff);
ang=acosd(pff);
Eff=sqrt((Vt*cosd(ang))^2+(Vt*sind(ang)+Ia*Xs)^2);
If=.9;
Iff=If*Eff/abs(Ef);
disp(Iff,'field current(A)');
```

Scilab code Exa 8.17 to calculate motor eff excitation emf and power angle max power op corresponding net op

```
//to calculate motor eff,excitation emf and power
   angle, max power op,corresponding net op

clc;
j=sqrt(-1);
Sop=40*1000;
Vt=600;
Ra=.8;
Xs=8;

Pst=2000;
Pmnet=30*1000;
Pm_dev=Pst+Pmnet;
Ia=Sop/(sqrt(3)*Vt);
Poh=3*Ia^2*Ra;
Pin=Pm_dev+Poh;
eff=(1-(Poh+Pst)/Pin)*100;disp(eff,'motor eff(%)');

cos_phi=Pin/(sqrt(3)*Vt*Ia);
```

```
phi=acosd(cos_phi);
Ia=Ia*(cosd(phi)+j*sind(phi));
Vt=Vt/sqrt(3);
Za=Ra+Xs*j;
Ef=Vt-Ia*Za;
Ef_line=Ef*sqrt(3);disp(Ef_line,'excitation emf(V)')
    ;
delta=atand(imag(Ef)/real(Ef));disp(delta,'power
    angle(deg)');
IaRa=abs(Ia)*Ra;
IaXs=abs(Ia)*Xs;
AD=Vt*cosd(phi)-IaRa;
CD=Vt*sind(phi)+abs(Ia)*Xs;
Ef_mag=sqrt((abs(AD))^2+(abs(CD))^2);

Pm_out_gross=-((abs(Ef_mag))^2*Ra/(abs(Za))^2)+(Vt*
    abs(Ef_mag)/abs(Za));
disp(Pm_out_gross,'max power op(W)');
power_angle=atand(imag(Za)/real(Za));
disp(power_angle,'power angle(deg)');
```

Scilab code Exa 8.18 find the change in the poweer angle

```
//find the change in the poweer angle;

clc;
Pe=4000;
V=400';
pf=.8;dl=acosd(pf);
Ia=Pe/(sqrt(3)*V*pf);
Vt=V/sqrt(3);
Xs=25;
Ef=Vt+j*Ia*complex(cosd(-dl),sind(-dl))*Xs;
a=atand(imag(Ef)/real(Ef));

```

```
dl=asind((Pe/3)*Xs/(Vt*abs(Ef)));
ang=dl+a;
disp(ang,'change in power angle(deg)');
```

Scilab code Exa 8.19 to find no of poles MVA rating prime mover rating and op torque

```
//to find no of poles ,MVA rating , prime mover rating
    and op torque

clc;
f=50;
n_s=100;
P=120*f/n_s;disp(P,'no of poles');
r=110;     //MVA rating
pf=.8;
rr=r/pf;disp(rr,'MVA rating');
eff=.971;
rt=r/eff;disp(rt,'prime mover rating(MW)');
T_PM=rt*1000*60/(2*%pi*n_s);disp(T_PM,'op torque(Nm)
    ');
```

Scilab code Exa 8.20 to determine the magnitude of Eg Em and min value of Em to remain mc in synchronism

```
//to determine the magnitude of Eg,Em and min value
    of Em to remain m/c in synchronism

clc;
j=sqrt(-1);
V_base=400;
kva_base=10;
MW_base=10;
```

```
Pm=8/10;
Vt=1;
pf=.8;
Ia=Pm/(Vt*pf);
Ia=Ia*complex(pf,sind(acosd(pf)));
Em=Vt-j*Ia*pf;
Emm=abs(Em)*V_base;
dl_m=atand(imag(Em)/real(Em));disp(dl_m,'dl_m(deg)');
Eg=Vt+j*Ia*(pf+.2);
Egg=abs(Eg)*V_base;
dl_g=atand(imag(Eg)/real(Eg));disp(dl_g,'dl_g(deg)');
dl_gm=dl_g-dl_m;disp(dl_gm,'relative angle(deg)');

dl_m=90;
Emmin=.8*.8/1;
disp(Emmin*V_base,'min value of Em(V)');
```

Scilab code Exa 8.21 to determine armature current pf power angle mech power developed and eff

```
//to determine armature current,pf,power angle,mech power developed and eff

clc;
j=sqrt(-1);
Vt=3300/sqrt(3);
Ef=4270/sqrt(3);
Pein=750000/3;
Zs=.8+j*5.5;
a=90-atand(imag(Zs)/real(Zs));
dl=asind((Pein-real(Zs)*(Vt/abs(Zs))^2)/((Vt*Ef/abs(Zs))))+a;
disp(dl,'power angle(deg)');
```

```
b=Vt-Ef*complex(cosd(-dl),sind(-dl));
Ia=b/Zs;
disp(abs(Ia),'armature current(A)');
phi=atand(imag(Ia)/real(Ia));
disp(cosd(phi),'pf');
Ef=sqrt(3)*Ef*complex(cosd(-dl),sind(-dl));
Pm=sqrt(3)*abs(Ef)*abs(Ia)*cosd(dl+phi);
disp(Pm,'mech power developed(W)');
Pst=30000;
Pmnet=Pm-Pst;
eff=Pmnet/(Pein*3);disp(eff*100,'efficiency(%)');
```

Scilab code Exa 8.22 to find armature current power factor and power ip

```
//to find armature current,power factor and power ip

clc;
j=sqrt(-1);
Vt=3300/sqrt(3);
Ef=4270/sqrt(3);
Pein=600000/3;
Zs=.8+j*5.5;
a=90-atand(imag(Zs)/real(Zs));
dl=asind((Pein+real(Zs)*(Ef/abs(Zs))^2)/((Vt*Ef/abs(
   Zs))))-a;
disp(dl,'power angle');
b=Vt-Ef*complex(cosd(-dl),sind(-dl));
Ia=b/Zs;
disp(abs(Ia),'armature current(A)');
phi=atand(imag(Ia)/real(Ia));
disp(cosd(phi),'pf');

Peinn=sqrt(3)*3300*abs(Ia)*cosd(phi);
disp(Peinn,'power ip(W)');
loss=Peinn-Pein*3;
```

```
disp(loss,'ohmic loss(W)');
```

Scilab code Exa 8.23 to calculate pu adjusted sync reactance feild reactance reactive power op rotor power angle

```
//to calculate pu adjusted sync reactance, feild
   reactance, reactive power op, rotor power angle

clc;
j=sqrt(-1);
r=10*10^6;
V_SC=13.8*10^3;
Ia=r/(sqrt(3)*V_SC);
If=226;

Iff=842;
I_SC=Ia*Iff/If;
Xsadj=(V_SC/sqrt(3))/I_SC;

va_b=10*10^6;
v_b=13800;
Xspu=Xsadj*va_b/v_b^2;disp(Xspu,'Xs(pu)');
Ra=.75;
Zs=Ra+j*Xsadj;
a=90-atand(imag(Zs)/real(Zs));

pf=.9;
phi=acosd(pf);
Pe=8.75*10^6;
Qe=Pe*tand(phi);
Vt=V_SC/sqrt(3);
Ia=(Pe/3)/(Vt*pf);
Ef=Vt+abs(Ia)*abs(Zs)*complex(cosd(90-a-phi),sind
   (90-a-phi));
Ef=abs(Ef)*sqrt(3);
```

```
If=Iff*Ef/V_SC;disp(If,'field current(A)');
loss=3*abs(Ia)^2*Ra;
Pmin=Pe+loss;disp(Pmin,'reactive power op(W)');

If=842;
Voc=7968;
Pmin=Pmin/3;
dl=asind((Pmin-real(Zs)*(Voc/abs(Zs))^2)/((Voc^2/abs
    (Zs))))+a;
disp(dl,'power angle');
Q=-(Voc/abs(Zs))^2*imag(Zs)+Voc^2*cosd(dl+a)/abs(Zs)
    ;
disp(Q,'reactive power op(VAR)');
```

Scilab code Exa 8.25 to calculate the excitation emf power angle

```
//to calculate the excitation emf,power angle

clc;
Vt=1;
Ia=1;
pf=.8;phi=acosd(pf);
Iaa=Ia*complex(cosd(-phi),sind(-phi));
Xq=.5;
j=sqrt(-1);
Ef=Vt+j*Iaa*Xq;

dl=17.1;
w=phi+dl;
Id=Ia*sind(w);
Xd=.8;
CD=Id*(Xd-Xq);
Eff=abs(Ef)+CD;
Ef=Vt+j*Iaa*Xd;
disp(abs(Ef),'excitation emf(V)');
```

```
disp(atand(imag(Ef)/real(Ef)),'power angle');
```

Scilab code Exa 8.26 calculate excitation emf

```
//calculate excitation emf

clc;
V=3300;
Vt=V/sqrt(3);
pf=1;
phi=acosd(pf);
P=1500*1000;
Ia=P/(sqrt(3)*V*pf);
Xq=2.88;
Xd=4.01;
w=atand((Vt*0-Ia*Xq)/Vt);
dl=phi-w;
Id=Ia*sind(w);
Iq=Ia*cosd(w);
Ef=Vt*cosd(dl)-Id*Xd;
disp(Ef*sqrt(3),'excitation emf(line)(V)');
```

Scilab code Exa 8.27 to calculate generator terminal voltage excitation emf power angle

```
//to calculate generator terminal voltage,excitation
    emf,power angle

clc;
Xd=1.48;
Xq=1.24;
Xe=.1;
Xdt=Xd+Xe;
```

```
Xqt=Xq+Xe;

MVA=1;
Vb=1;
pf=.9;
phi=acosd(pf);
//(Vt*cosd(phi))^2+(Vt*sind(phi)+Ia*Xe)^2=Vb^2;
//after solving
//Vt^2-.0870*Vt-.99=0;
function [x]=quad(a,b,c)
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
    if(x1<Vb)
        x=x2;
    else
        x=x1;
    end
endfunction
Vt=quad(1,-.0870,-.99);disp(Vt,'terminal voltage(V)'
   );
//after solving
phi=20;

j=sqrt(-1);
Ia=1;
Iaa=Ia*complex(cosd(-phi),sind(-phi));
Ef=Vb+j*Iaa*Xqt;
Eff=abs(Ef);
dl=atand(imag(Ef)/real(Ef));disp(dl,'power angle');
w=dl+phi;
Id=Ia*sind(w);
Ef=Ef+Id*(Xdt-Xqt);
disp(abs(Ef),'excitation emf(V)');
```

Scilab code Exa 8.28 to find max pu power pu armature current pu reactive power

```
//to find max pu power, pu armature current, pu
   reactive power

clc;
Vt=1;
Xd=1.02;
Xq=.68;
Pmmax=Vt^2*(Xd-Xq)/(2*Xd*Xq);disp(Pmmax,'max pu
   power');
dl=.5*asind(Pmmax/(Vt^2*(Xd-Xq)/(2*Xd*Xq)));

Id=Vt*cosd(dl)/Xd;
Iq=Vt*cosd(dl)/Xq;
Ia=sqrt(Id^2+Iq^2);disp(Ia,'armature current(pu)');

Qe=Id*Vt*cosd(dl)+Iq*Vt*sind(dl);disp(Qe,'reactive
   power(pu)');

pf=cosd(atand(Qe/Pmmax));disp(pf,'pf');
```

Scilab code Exa 8.29 to calculate power angle excitation emf field current

```
//to calculate power angle,excitation emf,field
   current

clc;
j=sqrt(-1);
MVA_b=300;
kV_b=22;

Pe=250/MVA_b;
pf=.85;
```

```
Vt=1;
Ia=Pe/(pf*Vt);
phi=acosd(pf);
Iaa=Ia*complex(cosd(-phi),sind(-phi));
Xq=1.16;
Xd=1.93;
Ef=Vt+j*Iaa*Xq;
dl=atand(imag(Ef)/real(Ef));disp(dl,'power angle');
w=phi+dl;
Id=abs(Iaa)*sind(w);
Ef=abs(Ef)+Id*(Xd-Xq);
disp(Ef*kV_b,'excitation emf(V)');

If=338;
If=If*Ef/1;disp(If,'field current(A)');
```

Scilab code Exa 8.30 to find max andmin pu field excitation

```
//to find max andmin pu field excitation

clc;
Xd=.71;
Xq=.58;
Xe=.08;
Xdt=Xd+Xe;
Xqt=Xq+Xe;

Pe=0;Vt=1;
dl=0;
phi=90;
Ia=1;
Iq=0;
Id=Ia;

Ef=Vt+Id*Xdt;
```

```
Ifmax=Ef;disp(Ifmax,'max field excitation(A)');


Ef=Vt-Id*Xdt;
Ifmin=Ef;disp(Ifmin,'min field excitation(A)');
```

Scilab code Exa 8.31 to calculate synchronising power and torque coeff per deg mech shift

```
//to calculate synchronising power and torque coeff/deg mech shift

clc;
V=11000;
Vt=V/sqrt(3);
P=6*10^6;
Ia=P/(sqrt(3)*V);
ohm_b=Vt/Ia;
Xs=.5;
Xss=Xs*ohm_b;

f=50;
P=8;
n_s=(120*f/P)*(2*%pi/60);

Ef=Vt;
dl=0;
Psyn=(%pi/15)*(Ef*Vt/Xss)*cosd(dl);disp(Psyn,'synchronising power(W)');
Tsyn=Psyn/n_s;disp(Tsyn,'torque coeff(Nm)');

pf=.8;
phi=acosd(pf);
Ef=Vt+j*Ia*Xss*complex(cosd(-phi),sind(-phi));
dl=atand(imag(Ef)/real(Ef));
```

```
Psyn=(%pi/15)*(abs(Ef)*Vt/Xss)*cosd(dl);disp(Psyn,'
    synchronising power(W)');
Tsyn=Psyn/n_s;disp(Tsyn,'torque coeff(Nm)');
```

Scilab code Exa 8.32 to calculate syncronising power per elec deg pu sync torque per mech deg

```
//to calculate syncronising power/elec deg,pu sync
    torque/mech deg

clc;
j=sqrt(-1);
Xd=.8;
Xq=.5;
Vt=1;
pf=.8;
phi=acosd(pf);
Ia=1*complex(cosd(phi),sind(phi));

Ef=Vt-j*Ia*Xq;
Eff=abs(Ef);
dl=atand(imag(Ef)/real(Ef));
w=-dl+phi;
Id=abs(Ia)*sind(w);
Ef=Eff+Id*(Xd-Xq);

Psyn=abs(Ef)*Vt*cosd(dl)/Xd+Vt^2*((Xd-Xq)/(Xd*Xq))*
    cosd(2*dl);
disp(Psyn*(%pi/180),'syncronising power(pu)/elec deg
    ');
f=50;
P=12;
n_s=(120*f/P)*(2*%pi/60);
Tsyn=Psyn/n_s;disp(Tsyn,'pu sync torque/mech deg');
```

Scilab code Exa 8.33 to calculate sync current power and torque

```
//to calculate sync current , power and torque

clc;
j=sqrt(-1);
P=12000;
V=400;
pf=.8;
Ia=P/(sqrt(3)*V*pf);
phi=acosd(pf);
Vt=V/sqrt(3);
Xs=2.5;
Ef=Vt-j*Ia*complex(cosd(phi),sind(phi))*Xs;
tandl=4;
Es=2*abs(Ef)*sind(tandl/2);
Is=Es/Xs;disp(Is,'sync current(A)');
dl=atand(imag(Ef)/real(Ef));
Ps=3*Vt*Is*cosd(dl+tandl/2);disp(Ps,'power(W)');
n_s=25*%pi;
T_s=Ps/n_s;
disp(T_s,'torque(Nm)');
```

Scilab code Exa 8.34 to calculate value of syncpower

```
//to calculate value of syncpower

clc;
V=6600;
E=V/sqrt(3);

P=12;
```

```
dl=1*P/2;

r=20000*10^3;
I=r/(sqrt(3)*V);
Xs=1.65;

Psy=dl*(%pi/180)*E^2/Xs;
disp(Psy,'sync power(W)');
```

Scilab code Exa 8.35 to determine op current and pf

```
//to determine op current and pf

clc;
P1=400*10^3;
P2=400*10^3;
P3=300*10^3;
P4=800*10^3;
pf1=1;
pf2=.85;
pf3=.8;
pf4=.7;
phi1=acosd(pf1);
phi2=acosd(pf2);
phi3=acosd(pf3);
phi4=acosd(pf4);
P=P1+P2+P3+P4;
Q1=P1*tand(phi1);
Q2=P2*tand(phi2);
Q3=P3*tand(phi3);
Q4=P4*tand(phi4);
Q=Q1+Q2+Q3+Q4;

I=100;
pf=.9;
```

```
V=6600;
P_A=sqrt(3)*V*I*pf;
P_B=P-P_A;
Q_A=P_A*tand(acosd(pf));
Q_B=Q-Q_A;
phi=atand(Q_B/P_B);
pf=cosd(phi);disp(pf,'pf');
I_B=P_B/(sqrt(3)*pf*V);disp(I_B,'op current(A)');
```

Scilab code Exa 8.36 to find the pf and current supplied by the mc

```
//to find the pf and current supplied by the m/c

clc;
P=50000;
pf=.8;
phi=acosd(pf);
Q=P*tand(phi);
P1=P/2;
pf1=.9;
phi1=acosd(pf1);
Q1=P1*tand(phi1);
P2=P/2;
Q2=Q-Q1;
phi2=atand(Q2/P2);
pf=cosd(phi2);disp(pf,'pf');
V_L=400;
I2=P2/(sqrt(3)*V_L*pf);disp(I2,'current supplied by
   m/c(A)');
```

Scilab code Exa 8.37 to find initial current current at the end of 2 cycles and at the end of 10s

```
//to find initial current ,current at the end of 2 cycles and at the end of 10s

clc;
Ef=1;
Xd2=.2;
I2=Ef/Xd2;
r=100*10^6;
V=22000;
I_b=r/(sqrt(3)*V);
I2=I2*I_b;disp(I2,'initial current(A)');

Xd1=.3;
I1=Ef/Xd1;
Xd=1;
I=Ef/Xd;

tau_dw=0.03;
tau_f=1;

function[a]=I_sc(t)
    a=(I2-I1)*exp(-t/tau_dw)+(I1-I)*exp(-t/tau_f)+1;
endfunction
//2 cycles=0.04s
disp(I_sc(.2867)*I_b,'current at the end of 2 cycles (A)');
disp(I_sc(10)*I_b,'current at the end of 10s(A)');
```

Scilab code Exa 8.39 to calculate sync reactance voltage regulation torque angle ele power developed voltage and kva rating

```
//to calculate sync reactance ,voltage regulation , torque angle , ele power developed , voltage and kva rating

```

```
clc;
r=1000*10^3;
V=6600;
Ia=r/(sqrt(3)*V);
pf=.75;
phi=-acosd(pf);
Vt=V/sqrt(3);
Ef=11400/sqrt(3);
//Ef*complex(cosd(dl),sind(dl))=Vt+j*Xs*Ia*complex(
    cosd(phi),sind(phi))
//after solving
//6.58*cosd(dl)=3.81+.058*Xs;
//6.58*sind(dl)=.0656*Xs;
//so after solving
//cosd(dl-phi)=.434;
dl=acosd(.434)+phi;

Xs=Ef*sind(dl)/65.6;disp(Xs,'sync reactance(ohm)');
vr=Ef*sqrt(3)/V-1;disp(vr,'voltage regulation(%)');
disp(dl,'torque angle(deg)');
P=3*Ef*Ia*cosd(dl-phi);disp(P,'ele power developed(W
    )');

volr=V/sqrt(3);disp(volr,'voltage rating(V)');
ir=Ia*sqrt(3);disp(ir,'current rating(A)');
r=sqrt(3)*volr*ir;disp(r,'VA rating');
```

Scilab code Exa 8.40 to determine mc and pf

```
//to determine m/c and pf

clc;
j=sqrt(-1);
P=230*10^6;
V=22000;
```

```
pf=1;
Ia=P/(sqrt(3)*V*pf);
Vt=V/sqrt(3);
Xs=1.2;
Ef=Vt+j*Xs*Ia;
//if Ef is inc by 30%
Ef=1.3*abs(Ef);

dl=asind((P/3)*Xs/(Ef*Vt));
Ia=((Ef*complex(cosd(dl),sind(dl)))-Vt)/(j*Xs);
disp(abs(Ia),'m/c current(A)');
disp(cosd(atand(imag(Ia)/real(Ia))),'pf');

P=275*10^6;
dl=asind((P/3)*Xs/(Ef*Vt));
Ia=((Ef*complex(cosd(dl),sind(dl)))-Vt)/(j*Xs);
disp(abs(Ia),'m/c current(A)');
disp(cosd(atand(imag(Ia)/real(Ia))),'pf');
```

Scilab code Exa 8.41 to calculate excitation emf torque angle eff shaft op

```
//to calculate excitation emf,torque angle, eff,
   shaft op

clc;
j=sqrt(-1);
Va=.8;
Xa=5.5;
Xs=Va+j*Xa;
V=3300;
Ia=160;
pf=.8;
loss=30000;
phi=acosd(pf);
Ef=V/sqrt(3)-Xs*Ia*complex(cosd(-phi),sind(-phi));
```

```
disp(abs(Ef),'excitation emf(V)');
dl=atand(imag(Ef)/real(Ef));disp(dl,'torque angle(deg)');
P_mech=3*abs(Ef)*Ia*cosd(-phi-dl);
op_sft=P_mech-loss;disp(op_sft,'shaft op(W)');
Pip=sqrt(3)*V*Ia*pf;
eff=op_sft/Pip;disp(eff*100,'efficiency(%)');
```

Scilab code Exa 8.42 to caculate generator current pf real power excitation emf

```
//to caculate generator current,pf, real power, ecitation emf

clc;
r=500*10^6;
V=22000;
Ia=r/(sqrt(3)*V);disp(Ia,'generator current(A)');
Vt=V/sqrt(3);
Zb=Vt/Ia;
MVA_b=500;
MW_b=500;
Xsg=1.57;
Xb=.4;
Xb=Xb/Zb;

rr=250;
rr=rr/MVA_b;
Vb=1;
Vt=1;
Ia=.5;
phi=asind(Xb*Ia/2);
pf=cosd(phi);disp(pf,'pf');
Pe=rr*pf;disp(Pe,'real power(pu)');
Eg=Vt+j*Xsg*rr**complex(cosd(-phi),sind(-phi));
```

```
Egg=abs(Eg)*V;disp(Egg,'excitation emf(V)');


rr=500;
rr=rr/MVA_b;
Vb=1;
Vt=1;
Ia=1;
phi=asind(Xb*Ia/2);
pf=cosd(phi);disp(pf,'pf');
Pe=rr*pf;disp(Pe,'real power(pu)');
Eg=Vt+j*Xsg*rr*complex(cosd(-phi),sind(-phi));
Egg=abs(Eg)*V;disp(Egg,'excitation emf(V)');
```

Scilab code Exa 8.43 to clculate pf angle torque angle equivalent capicitor and inductor value

```
//to clculate pf angle, torque angle,equivalent
   capicitor and inductor value

clc;
of1=250;
scr=.52;     //short ckt ratio
of2=of1/scr;
r=25*10^6;
V=13000;
Ia=r/(sqrt(3)*V);
Isc=Ia*of1/of2;
Xs=V/(sqrt(3)*Isc);
Xb=V/(sqrt(3)*Ia);
Xsadj=Xs/Xb;

f=50;
If=200;
Ef=V*If/of1;
```

```
Vt=V/sqrt(3);
Ia=(Vt-Ef/sqrt(3))/Xs;
dl=0;disp(dl,'torque angle(deg)');
pf=90;disp(pf,'pf angle(deg)');
L=(V/(sqrt(3)*Ia))/(2*%pi*f);
disp(L,'inductor value(H)');

If=300;
Eff=V*If/of1;
Vt=Ef/sqrt(3);
Ia=(Eff/sqrt(3)-Vt)/Xs;
dl=0;disp(dl,'torque angle(deg)');
pf=90;disp(pf,'pf angle(deg)');
c=1/((V/(Ia))*(2*%pi*f));
disp(c,'capacitor value(F)');
```

Scilab code Exa 8.44 to determine Xs saturated scr Xs unsat and If generator current

```
//to determine Xs(saturated),scr,Xs(unsat)and If,
   generator current

clc;
MVA_b=400;
kV_b=22;
Ib=MVA_b/(sqrt(3)*kV_b);
ohm_b=kV_b/(sqrt(3)*Ib);

If=1120;
Voc=kV_b/sqrt(3);
Isc=13.2;
Xssat=Voc/Isc;disp(Xssat,'Xs(saturated)(ohm)');
Xss=Xssat/ohm_b;disp(Xss,'Xs(saturated)(pu)');
scr=1/Xss;disp(scr,'SCR');
Isc=Ib;
```

```
Voc=24.4/sqrt(3);
Xsunsat=Voc/Isc;disp(Xsunsat,'Xs(unsaturated)(ohm)')
    ;
Xsuns=Xsunsat/ohm_b;disp(Xsuns,'Xs(unsaturated)(pu)'
    );
Iff=If*scr;disp(Iff,'generator current(A)');
```

Scilab code Exa 8.45 find motor pf

```
//find motor pf

clc;
j=sqrt(-1);
V=6600;
Vt=V/sqrt(3);
pf=.8;
phi=acosd(pf);
P=800000;
Ia=P/(sqrt(3)*V*pf);
Zs=2+20*j;
Ef=Vt-Zs*Ia*complex(cosd(phi)+sind(phi));
Pip=1200*10^3;
theta=atand(imag(Zs)/real(Zs));
dl=acosd((real(Ef)^2*cosd(theta)/abs(Zs)-P/3)/(real(
    Ef)*abs(Ef)/abs(Zs)))-theta;

Ia=(real(Ef)-abs(Ef)*complex(cosd(-dl),sind(-dl)))/
    Zs;
phi=atand(imag(Ia)/real(Ia));
disp(cosd(phi),'pf');
```

Scilab code Exa 8.46 to find exciting emf neglecting saliency and accounting saliency

```
//to find exciting emf neglecting saliency and
   accounting saliency

clc;
j=sqrt(-1);
Xd=.12/3;
Xq=.075/3;

disp('neglecting saliency');
Xs=Xd;
V=440;
pf=.8;
phi=acosd(pf);
Vt=V/sqrt(3);
Ia=1000;
Ef=Vt+j*Xs*Ia*complex(cosd(-phi),sind(-phi));
disp(abs(Ef)*sqrt(3),'excitation emf(line)(V)');
disp('accounting saliency');
w=atand((Vt*sind(phi)+Ia*Xq)/(Vt*cosd(phi)));
dl=w-phi;
Ef=Vt*cosd(dl)+Ia*sind(dl)*Xd;
disp(abs(Ef)*sqrt(3),'excitation emf(line)(V)');
```

Scilab code Exa 8.47 calculate excitation emf max load motor supplies torque angle

```
//calculate excitation emf,max load motor supplies,
   torque angle

clc;
Xd=23.2;
Xq=14.5;
V=6600;
pf=.8;
phi=acosd(pf);
```

```
Vt=V/sqrt(3);
r=1500*1000;
Ia=r/(sqrt(3)*V)
w=atand((Vt*sind(-phi)-Ia*Xq)/(Vt*cosd(phi)));
dl=-phi-w;disp(dl,'torque angle');
Ef=Vt*cosd(dl)-Ia*sind(w)*Xd;
disp(Ef,'excitation emf(V)');

Pe=V^2*((Xd-Xq)/(2*Xd*Xq));disp(Pe,'load supplied(W)
    ');
```

Scilab code Exa 8.49 find no load freq setting sys freq at no load freq of swing generator system trip freq

```
//find no load freq setting,sys freq,at no load freq
    of swing generator, system trip freq

clc;
loadtot=260;
r=125;
pf=.84;
genfl=r*pf;
sld=75;    //supply load
n=3;    //no of generators
ls=loadtot-n*sld;
m=-5/genfl;
f=50;
ff=f-m*sld;disp(ff,'set freq(Hz)');
c=f-m*ls;disp(c,'set freq(Hz) supplied from swing
    generator');
nld=sld+50/4;
c=ff+m*nld;disp(c,'new system freq(Hz)');
rld=310-n*sld;
c=f-m*rld;disp(c,'set freq(Hz) of swing generator');
nld=310/n;
```

```
c=ff+m*nld;disp(c,'system trip freq(Hz)');
```

Chapter 9

Induction Machine

Scilab code Exa 9.1 to campute cu loss in rotoe windings input to the motor efficiency

```
// to campute cu loss in rotoe windings , input to
   the motor , efficiency

clc;
f_s=120/60;          //cycles/min
f=50;
s=f_s/f;
n_s=1000;
n=(1-s)*n_s;
w=n*2*%pi/60;
T=160;
P=T*w;
T_L=10;
P_m=(T+T_L)*w;
cu=P_m*(s/(1-s));    disp(cu,'rotor cu loss(W)');

P_sl=800;     //stator loss
P_in=P_m+cu+P_sl;    disp(P_in,'power i/p to motor(W
   )');

```

```
eff=P/P_in;
disp(eff*100,'efficiency(%)');
```

Scilab code Exa 9.2 to calculate torque resistance to be added to rotor ckt

```
//to calculate torque,resitance to be added to rotor ckt

clc;
f=50;
P=6;
n_s=120*f/P;
w_s=2*%pi*n_s/60;
n=875;
s_maxT=(n_s-n)/n_s;
R_2=.25;
X_2=R_2/s_maxT;
T_max=10;
//v=V/a
v=sqrt((T_max*w_s*X_2)/(3*.5));
T=((3)*v^2*(R_2/s))/(w_s*((R_2/s)^2+(X_2)^2));
disp(T,'torque(Nm)');

//from eqn(T_start/T_max)=(R2+Rext)*(X2/.5)/((R2+Rext)^2+X2^2)
//after solving
//Rt^2-6.67*Rt+4=0
function [x]=quad(a,b,c)
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
    if(x1>x2)
        x=x2;
    else
```

```
        x=x1;
    end
endfunction
Rt=quad(1,-6.67,4);
r2=.25;
disp(Rt-r2,'external resistance(ohm)');
```

Scilab code Exa 9.3 to find slip at max torque full load slip and rotor current at starting

```
//to find slip at max torque,full load slip and
   rotor current at starting

clc;
//Tfl=(3/w_s)*(V^2*Rs/s_fl)/((R2/s_fl)^2+X2^2);       (
   i)
//Ts=(3/w_s)*(V^2*R2)/(R2^2+X2^2);      (ii)
//Tmax=(3/w_s)*(.5*V^2)/X2^2;      (iii)
//Tmax/Ts=2;      k=R2/X2;      (iii)/(ii)and solving
//k^2-4*k+1=0;
function [x]=quad(a,b,c)
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
    if(x1>x2)
        x=x2;
    else
        x=x1;
    end
endfunction
k=quad(1,-4,1);
disp(k,'s_max_T');

//(iii)/(i)and solving
//s_fl^2-1.072*s_fl+.072=0
```

```
s_fl=quad(1,-1.072,.072);
disp(s_fl,'s_fl');

//a=I2_start/I2_fullload
a=sqrt((k/s_fl)^2+1)/(k^2+1);
disp(a,'I2_start/I2_fullload');
```

Scilab code Exa 9.4 to calculate stator current pf net mech op torque motor performance

```
//to calculate stator current,pf, net mech o/p,
   torque, motor performance

clc;
j=sqrt(-1);
Vt=400;
P=6;
f=50;
Inl=7.5;
Pnl=700;
disp('block rotor test results');
Vbr=150;
Ibr=35;
Pinbr=4000;
R1=.55;disp(R1,'R1(ohm)');
k=1/.5;
s=0.04;
Zbr=Vbr/(sqrt(3)*Ibr);
Rbr=Pinbr/(3*Ibr^2);
Xbr=sqrt(Zbr^2-Rbr^2);
X1=Xbr/(1+.5);disp(X1,'X1(ohm)');
X2=Xbr-X1;disp(X2,'X2(ohm)');
disp('no load test results');
Zo=Vt/(sqrt(3)*Inl);
Ro=Pnl/(3*Inl^2);
```

```
Xo=sqrt(Zo^2-Ro^2);
Xm=Xo-X1;disp(Xm,'Xm(ohm)');
R2=(Rbr-R1)*((Xm+X2)/Xm)^2;disp(R2,'R2(ohm)');
Zf=1/((1/(j*Xm))+(1/((R2/s)+j*X2)));
Rf=real(Zf);
Xf=imag(Zf);
Zin=R1+j*X1+Zf;
I1=Vt/(sqrt(3)*Zin);
Pin=sqrt(3)*Vt*abs(I1)*cosd(atand(imag(I1)/real(I1))
    );disp(Pin,'Pin(W)');
Pg=3*abs(I1)^2*Rf;disp(Pg,'Pg(W)');
Pm=(1-s)*Pg;disp(Pm,'Pm(W)');
Prot=Pnl-3*Inl^2*R1;disp(Prot,'Prot(W)');
Pout=Pm-Prot;disp(Pout,'Pout(W)');
w_s=1000*2*%pi/60;
Tnet=Pout/((1-s)*w_s);disp(Tnet,'Tnet(Nm)');
eff=Pout*100/Pin;disp(eff,'eff(%)');
```

Scilab code Exa 9.5 to determine ckt model parameters parameters of thevenin equivalent max torque and slip stator current pf and eff

```
//to determine ckt model parameters,parameters of
    thevenin equivalent, max torque and slip, stator
    current, pf and eff

clc;
j=sqrt(-1);
//NL test
V=3300;
f=50;
Inl=5;
Po=2500;
Zo=V/(sqrt(3)*Inl);
Ro=Po/(3*Inl^2);disp(Ro,'Ro(ohm)');
Xo=sqrt(Zo^2-Ro^2);disp(Xo,'Xo(ohm)');
```

```
//BR test
V_BR=400;
I_BR=27;
ff=15;
P_BR=15000;
Z_BR=V_BR/(sqrt(3)*I_BR);
R_BR=P_BR/(3*I_BR^2);
X_BR=sqrt(Z_BR^2-R_BR^2);
x1=X_BR/2;      //at 15 Hz
X1=x1*f/ff;     //at 50Hz
disp(X1,'X1(ohm)');
Xm=Xo-X1;disp(Xm,'Xm(ohm)');
R1=3.75;
R2=(R_BR-R1)*((Xm+X1)/Xm)^2;disp(R2,'R2(ohm)');

V_TH=(V/sqrt(3))*complex(cosd(0),sind(0))*complex(0,
    Xm)/complex(R1,X1+Xm);
disp(V_TH,'V_TH(V)');
Z_TH=complex(0,Xm)*complex(R1,X1)/complex(R1,X1+Xm);
disp(real(Z_TH),'R_TH(ohm)');
disp(imag(Z_TH),'X_TH(ohm)');

a=(sqrt(real(Z_TH)^2+(X1+imag(Z_TH))^2));
s_max_T=R2/a;
n_s=1000;
Z_tot=complex(real(Z_TH)+a,X1+imag(Z_TH));
I2=abs(V_TH)/abs(Z_tot);
T_max=3*(I2^2)*R2/(s_max_T*(2*%pi*n_s/60));disp(
    T_max,'T_max(Nm)');

Z_f=complex(0,Xm)*complex(81.25,X1)/complex(81.25,X1
    +Xm);
Z_in=Z_f+complex(R1,X1);
I1=V/(sqrt(3)*abs(Z_in));
pf=cosd(atand(imag(Z_in)/real(Z_in)));
s=.04;
Pmechg=(1-s)*3*I1^2*real(Z_f);
Prot=Po-Inl^2*R1;
```

```
Pip=sqrt(3)*V*I1*pf;
Pop=Pmechg-Prot;
eff=Pop/Pip;disp(eff,'efficiency');
Tint=Pmechg/((1-s)*2*%pi*n_s/60);disp(Tint,'internal
    torque developed(Nm)');
```

Scilab code Exa 9.6 to calculate starting torque and current full load current pf torque internal and overall eff slip and max torque

```
//to calculate starting torque and current,full load
    current,pf, torque , internal and overall eff,
   slip and max torque

clc;
R1=.3;
R2=.25;
X1=.6;
X2=.6;
Xm=35;
Prot=1500;
V=231;
Z_TH=complex(0,Xm)*complex(R1,X1)/complex(R1,X1+Xm);
V_TH=(V*complex(0,Xm))/complex(R1,X1+Xm);
n_s=1500;
w_s=2*%pi*n_s/60;

s=1;
Z_f=complex(0,Xm)*complex(R2,X2)/complex(R2,X2+Xm);
R_f=real(Z_f);
Z_in=Z_f+complex(R1,X1);
I1=V/abs(Z_in);disp(I1,'starting current(A)');
Tstart=3*I1^2*R_f/w_s;disp(Tstart,'starting torque(
   Nm)');

n=1450;
```

```
s=1-n/n_s;
a=R2/s;
Z_f=complex(0,Xm)*complex(a,X2)/complex(a,X2+Xm);
R_f=real(Z_f);
Z_in=Z_f+complex(R1,X1);
I1=V/abs(Z_in);disp(I1,'full load current(A)');
pf=cosd(atand(imag(Z_in)/real(Z_in)));disp(pf,'pf');
P_G=3*I1^2*R_f;
Popg=P_G*(1-s);
Pop=Popg-Prot;
Tnet=Pop/((1-s)*w_s);disp(Tnet,'net torque(Nm)');
Vt=400;
Pip=sqrt(3)*Vt*I1*pf;
eff=Pop/Pip;disp(eff*100,'efficiency(%)');
int_eff=Popg/Pip;disp(int_eff*100,'internal eff(%)');

s_max_T=1/(sqrt(real(Z_TH)^2+(imag(Z_TH)+X1)^2)/R2);disp(s_max_T,'max slip');
Z_tot=Z_TH+complex(R2/s_max_T,X2);
I2=abs(V_TH)/abs(Z_tot);
T_max=3*I2^2*(R2/s_max_T)/w_s;
disp(T_max,'max torque(Nm)');
```

Scilab code Exa 9.9 to determine the line current pf power ip shaft torque mech op and efficiency

```
//to determine the line current,pf, power ip, shaft torque, mech op and efficiency

clc;
R1=1.4;
R2=.6;
X1=2;
X2=1;
```

```
Xm=50;
V=400;
Prot=275;
n_s=1000;
w_s=2*%pi*n_s/60;

disp('slip=0.03');
s=0.03;
I2=(V/sqrt(3))/complex(R1+R2/s,X1+X2);
Im=(V/sqrt(3))/(Xm*complex(cosd(90),sind(90)));
I1=Im+I2;
I_L=abs(I1);disp(I_L,'line current(A)');
pf=cosd(atand(imag(I1)/real(I1)));disp(pf,'pf');
Pip=sqrt(3)*V*abs(I1)*cosd(atand(imag(I1)/real(I1)));disp(Pip,'power i/p(W)');

P_G=3*abs(I2)^2*R2/s;
Pmechg=(1-s)*P_G;disp(Pmechg,'mech power op(W)');
Popnet=Pmechg-Prot;
Tnet=Popnet/(w_s*(1-s));disp(Tnet,'shaft torque(Nm)');
eff=Popnet/Pip;disp(eff,'efficiency');

disp('slip= -0.03');
s=-0.03;
I2=(V/sqrt(3))/complex(R1+R2/s,X1+X2);
Im=(V/sqrt(3))/(Xm*complex(cosd(90),sind(90)));
I1=-(Im+I2);
I_L=abs(I1);disp(I_L,'line current(A)');
pf=cosd(atand(imag(I1)/real(I1)));disp(pf,'pf');
Pip=sqrt(3)*V*abs(I1)*cosd(atand(imag(I1)/real(I1)));disp(Pip,'power i/p(W)');

P_G=3*abs(I2)^2*R2/s;
Pmechop=(1-s)*P_G;
Pmechipnet=-Pmechop;
Pmechipg=Pmechipnet+Prot;disp(Pmechipg,'mech power op(W)');
```

```
Tnet=Pmechipg/(w_s*(1-s));disp(Tnet,'shaft torque(Nm)');
eff=Pip/Pmechipg;disp(eff,'efficiency');

disp('slip= 1.2');
s=1.2;
I2=(V/sqrt(3))/complex(R1+R2/s,X1+X2);
Im=(V/sqrt(3))/(Xm*complex(cosd(90),sind(90)));
I1=Im+I2;
I_L=abs(I1);disp(I_L,'line current(A)');
pf=cosd(atand(imag(I1)/real(I1)));disp(pf,'pf');
Pip=sqrt(3)*V*abs(I1)*pf;disp(Pip,'power i/p(W)');

P_G=3*abs(I2)^2*.5/s;
Pmechg=(1-s)*P_G;disp(Pmechg,'mech power op(W)');
Pmechabs=-Pmechg;
n=n_s*(1-s);
w=2*%pi*n/60;
Tnet=Pmechg/w;disp(Tnet,'torque developed(Nm)');
P=Pmechabs+Pip;disp(P,'power disipated(W)');
```

Scilab code Exa 9.10 to calculate max torque and slip starting torque

```
//to calculate max torque and slip, starting torque

clc;
k=5;    //k=I_s/I_fl
s_fl=0.04;
s_max_T=sqrt((s_fl^2*(1-k^2))/((k*s_fl)^2-1));disp(s_max_T,'slip');
T_max=.5*(s_max_T^2+s_fl^2)/(s_fl*s_max_T);disp(T_max,'max torque(pu)');

T_s=k^2*s_fl;disp(T_s,'starting torque(pu)');
```

Scilab code Exa 9.11 to find starting current and torque necessary exteranl resistance and corresponding starting torque

```
//to find starting current and torque, necessary exteranl resistance and corresponding starting torque

clc;
f=50;
R2=.1;
X2=2*%pi*f*3.61*10^-3;
a=3.6;
R22=a^2*R2;
X22=a^2*X2;
V=3000;
n_s=1000;
w_s=2*%pi*n_s/60;
I_s=(V/sqrt(3))/sqrt(R22^2+X22^2);disp(I_s,'starting current(A)');
T_s=(3/w_s)*(V/sqrt(3))^2*R22/(R22^2+X22^2);disp(T_s,'torque(Nm)');

Iss=30;
Rext=sqrt(((V/sqrt(3)/Iss)^2-X22^2)-R22);
disp(Rext,'external resistance(ohm)');
T_s=(3/w_s)*(V/sqrt(3))^2*(R22+Rext)/((R22+Rext)^2+X22^2);disp(T_s,'torque(Nm)');
```

Scilab code Exa 9.12 find line current and starting torque with direct switching stator resistance starting autotransformer starting star delta starting autotransformer ratio give 1 pu

```
//find line current and starting torque with direct
   switching, stator resistance starting,
   autotransformer starting, star delta starting,
   autotransformer ratio give 1 pu

clc;
//I_s/I_fl=6;
s_fl=0.05;
disp('by direct switching');
Is=6;disp(Is,'line current(pu)');
T=Is^2*s_fl;disp(T,'torque(pu)');

disp('by stator resistance starting');
Is=2;disp(Is,'line current(pu)');        //given
T=Is^2*s_fl;disp(T,'torque(pu)');

disp('by autotransformer starting');
x=2/6;
Is_motor=2;
Is=Is_motor*x;disp(Is,'line current(pu)');
T=Is^2*s_fl;disp(T,'torque(pu)');

disp('by star delta starting');
Is=(1/3)*6;disp(Is,'line current(pu)');
T=Is^2*s_fl*3;disp(T,'torque(pu)');

disp('by autotransformer starting');
Ts=1;
x=sqrt(Ts/((6^2)*s_fl));disp(x,'x');
```

Scilab code Exa 9.13 to find resistance added to ckt

```
//to find resistance added to ckt

clc;
```

```
Rrot=.061;
R2=Rrot/2;
f=50;
P=12;
w_s=(120*f/P)*(2*%pi/60);
s=0.045;
w=(1-s)*w_s;
P=200*10^3;
T_fan=P/w;
I2=sqrt(T_fan*w_s*s/(3*R2));
E2=I2*R2/s;
n=450;
ww=2*%pi*n/60;
nn=500;
ss=(nn-n)/nn;
Tnew=T_fan*(ww/w)^2;
Rt=(3/w_s)*(E2*ss)^2/(ss*Tnew);
Rext=Rt-R2;disp(Rext,'external resistance(ohm)');
```

Scilab code Exa 9.14 to find resistance added to ckt

```
//to find resistance added to ckt

clc;
n_s=1500;
w_s=2*%pi*n_s/60;
n=1250;
s=1-n/n_s;
//Im=(1/3)*(0.3+.25/s+j*1.83)ohm/ph
T=150;
V=440;
//T=(3/w_s)*(V^2*(R_2t/s))/((.1+(R_2t/s))^2+(X1+X2)
    ^2);
//after solving R_2t^2-1.34*R_2t+0.093=0
function [x]=quad(a,b,c)
```

```
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
    if(x1>x2)
        x=x1;
    else
        x=x2;
    end
endfunction
[x]=quad(1,-1.34,0.093);
Rext=x-0.083;disp(Rext,'external resitance(ohm)');
```

Scilab code Exa 9.15 to calculate the min resistance to be added and speed of the motor

```
//to calculate the min resistance to be added and
   speed of the motor

clc;
V=400;
a=2.5;
X2=.4;
R2=0.08;
n_s=750;
w_s=2*%pi*n_s/60;
T=250;
//T=(3/w_s)*((V/sqrt(3))/a)*R2t/(R2t^2+X2^2);
//after solving
//R2t^2-1.304*R2t+0.16=0
function [x1,x2]=quad(a,b,c)
    d=sqrt(b^2-4*a*c);
    x1=(-b+d)/(2*a);
    x2=(-b-d)/(2*a);
endfunction
[x1 x2]=quad(1,-1.304,0.16);
```

```
    if(x1>x2)
        R2t=x2;
    else
        R2t=x1
    end
Rext=R2t-R2;
disp(Rext,'external resistance(ohm)');

//T=(3/w_s)*((V/sqrt(3))/a)*(R2t/s)/((R2t/s)^2+X2^2)
   ;
//after solving
//(R2t/s)^2-1.304*(R2t/s)+0.16=0
[x1 x2]=quad(1,-1.304,0.16);
s=x2/x1;
n=n_s*(1-s);
disp(n,'speed(rpm)');

//T=(3/w_s)*((V/sqrt(3))/a)*(R2/s)/((R2/s)^2+X2^2);
//after solving
//(R2/s)^2-1.304*(R2/s)+0.16=0
[x1 x2]=quad(1,-1.304,0.16);
R2=0.08;
s1=R2/x1;
s2=R2/x2;
if(s1>s2)
        ss=s2;
    else
        ss=s1
    end
n=n_s*(1-ss);
disp(n,'speed(rpm)');
```

Scilab code Exa 9.17 to find the ratio of currents and torques at the starting V2 by V1

```
//to find the ratio of currents and torques at the
   starting ,V2/V1

clc;
f1=50;
f2=60;
f=f2/f1;
V=1;    //V=V2/V1
s_max_T=0.2;
//Is=I_s2/I_s1
Is=V*sqrt((s_max_T^2+1)/(s_max_T^2+f^2));
disp(Is,'ratio of currents at starting');
//Ts=T_s2/T_s1
Ts=V^2*((s_max_T^2+1)/(s_max_T^2+f^2));
disp(Ts,'ratio of torques at starting');
//Tmax=Tmax2/Tmax1
Tmax=V^2/f^2;
disp(Tmax,'ratio of max torques');
Vr=sqrt(1/sqrt((s_max_T^2+1)/(s_max_T^2+f^2)));
disp(Vr,'V2/V1');
```

Scilab code Exa 9.18 to calculate ratio of torques at starting and given slip

```
//to calculate ratio of torques at starting and at
   slip =0.05

clc;
R1=0.01;
X1=.5;
R2=0.05;
X2=.1;
Ts=((R1^2+X1^2)/(R2^2+X2^2))*(R2/R1);
disp(Ts,'Tso/Tsi');

```

```
s=0.05;
T=(((R1/s)^2+X1^2)/((R2/s)^2+X2^2))*(R2/R1);
disp(T,'To/Ti');
```

Scilab code Exa 9.19 to compute acc time and value of rotor resistance

```
//to compute acc time and value of rotor resistance

clc;
s=1-.96;     //load is brought to .96 of n_s
s_max_T=sqrt((1-s^2)/(2*log(1/s)));
R=1.5;
R2_opt=R*s_max_T;disp(R2_opt,'rotor resistance(ohm)'
    );
n=1000;
w_s=2*%pi*n/60;
V=415;
Tmax=(3/w_s)*(.5*(V/sqrt(3))^2)/R;
J=11;
t_A=(J*w_s/(2*Tmax))*((1-s^2)/(2*s_max_T)+s_max_T*
    log(1/s));
disp(t_A,'acc time(min)');
```

Chapter 10

Fractional Kilowatt Motors

Scilab code Exa 10.1 to compute the ratio of Emf by Emb Vf by Vb Tf by Tb gross total torque Tf by total torque Tb by total torque

```
// to compute the ratio of E_mf/E_mb,V_f/V_b,T_f/T_b
   ,gross total torque,T_f/total torque, T_b/total
   torque

clc;
R_1m=3;
X_1m=5;
R_2=1.5;
X_2=2;
s=1-.97;          //slip
a=complex(R_2/s,X_2);
b=complex(R_2/(2-s),X_2);
c=abs(a)/abs(b);
disp(c,'E_mf/E_mb');
a=(1/2)*complex((R_1m+R_2/s),(X_1m+X_2));
b=(1/2)*complex((R_1m+R_2/(2-s)),(X_1m+X_2));
c=abs(a)/abs(b);
disp(c,'V_f/V_b');
d=(2-s)/s;
disp(d,'T_f/T_b');
```

```
Z_tot=a+b;
V=220;
I_m=V/abs(Z_tot);
P=6;
f=50;
n_s=120*f/P;
w_s=2*%pi*n_s/60;
T_f=(I_m^2*R_2/(2*w_s))*(1/s);
T_b=(I_m^2*R_2/(2*w_s))*(1/(2-s));
T_tot=T_f-T_b;
disp(T_tot,'gross total torque(Nm)');
a=T_f/T_tot;
b=T_b/T_tot;
disp(a,'T_f/T_total');
disp(b,'T_b/T_total');
```

Scilab code Exa 10.2 to calculate parameters of the ckt model line current power factor shaft torque and efficiency

```
// to calculate parameters of the ckt model, line
   current, power factor, shaft torque and
   efficiency

clc;
V_0=215;
I_0=3.9;
P_0=185;
R_1=1.6;
V_sc=85;
I_sc=9.8;
P_sc=390;
X=(V_0/I_0)*2;          //magnetisation reactance
phi_sc=acosd(P_sc/(V_sc*I_sc));
I_e=V_sc/complex(0,X);
I_SC=I_sc*complex(cosd(phi_sc*(-1)),sind(phi_sc*(-1)
```

```
));
I_m=I_SC-I_e;
Z=V_sc/I_m;
R_2=real(Z)-R_1;     //real(Z)=R=R1+R2
disp(R_2,'R_2(ohm)');
disp(imag(Z),'X_1+X_2(ohm)');

n=1500;    nn=1440;
s=(n-nn)/n;
a=1.55/s;
b=1.55/(2-s);
Z_ftot=(complex(0,X/2))*(complex(a+.8,imag(Z)/2))/((
    complex(0,X/2))+(complex(a+.8,imag(Z)/2)));
Z_btot=(complex(0,X/2))*(complex(b+.8,imag(Z)/2))/((
    complex(0,X/2))+(complex(b+.8,imag(Z)/2)));
Z_tot=Z_ftot+Z_btot;
I_m=V_0/Z_tot;
I_L=abs(I_m);disp(I_L,'line current(A)');
pf=cosd(atand(real(I_m)/imag(I_m)));    disp(pf,'pf'
    );
P_in=V_0*I_L*pf;
I_mf=I_m*complex(0,X/2)/complex(39.55,59.12);
I_mb=I_m*complex(0,X/2)/complex(1.59,59.12);
T=(1/157.1)*(abs(I_mf)^2*38.75-abs(I_mb)^2*.79);
P_m=157.1*(1-s)*T;
P_L=185;
P_out=P_m-P_L;
eff=P_out/P_in;    disp(eff*100,'efficiency(%)');
T_shaft=P_out/157.1;    disp(T_shaft,'shaft torque(
    Nm)');
```

Scilab code Exa 10.3 to compute ampitudes of forward and backward stator mmf waves magnitude of auxillary currrent and its ph angle diff

```
//to compute ampitudes of forward and backward
```

```
stator mmf waves,magnitude of auxillary currrent and its ph angle diff

clc;
N_m=80;
N_a=100;
I_m=15*complex(cosd(0),sind(0));
I_aa=7.5*complex(cosd(45),sind(45));
I_a=7.5*complex(cosd(60),sind(60));
F_m=N_m*I_m;
F_a=N_a*I_a;
F_aa=N_a*I_aa;     //mmf at 45 angle
F_f=(1/2)*(F_m+imult(F_aa));a=abs(F_f);
disp(a,'forward field(AT)');
F_b=(1/2)*(F_m-imult(F_aa));b=abs(F_b);
disp(b,'backward field(AT)');
//1200+100*I_a*complex(sind(a),cosd(a))=0
//equating real and imaginery parts
//100*I_a*cosd(a)=0;
a=90;
    disp(a,'phase angle diff');
I_a=-1200/(100*sind(a));    disp(I_a,'auxillery current(A)');
```

Scilab code Exa 10.4 to determine value of capacitor

```
//to determine value of capacitor

clc;
f=50;
w=2*%pi*f;
Z_lm=complex(3,2.7);
Z_la=complex(7,3);
I_m=(-1)*atand(imag(Z_lm)/imag(Z_la));
a=90;
```

```
I_a=a+I_m;
c=1/(w*(real(Z_lm)-real(Z_la)*tand((-1)*I_a)));
disp(c,'value of capacitor(F)');
```

Scilab code Exa 10.5 to calculate starting torque and current value of run capacitor motor performance

```
//to calculate starting torque and current,value of
   run capacitor,motor performance

clc;
R_lm=4.2;
X_lm=11.3;
R_la=5.16;
X_la=12.1;
X=250;
a=1.05;
R_2=7.48;
X_2=7.2;
Z_f=(complex(0,X)*complex(R_2,X_2))/(complex(0,X)+
   complex(R_2,X_2));
c=314*70*10^-6;
Z_la=complex(R_la,X_la-1/c);
Z_lm=complex(R_lm,X_lm);
Z_12=(1/2)*(Z_la/(a^2)-(Z_lm));
V=220;
V_mf=(V/2)*complex(1,-1/a);
V_mb=(V/2)*complex(1,1/a);
Z=Z_lm+Z_f+Z_12;
I_mf=(V_mf*Z+V_mb*Z_12)/(Z^2-Z_12^2);
I_mb=(V_mb*Z+V_mf*Z_12)/(Z^2-Z_12^2);
n_s=1500;
w_s=2*%pi*n_s/60;
T_s=(2/w_s)*real(Z_f)*(abs(I_mf)^2+abs(I_mb)^2);disp
   (T_s,'starting torque(Nm)');
```

```
I_m=I_mf+I_mb;
I_a=imult(I_mf-I_mb)/a;
I_L=I_m+I_a;
disp(abs(I_L),'I_L(start)(A)');

s=.04;
Z_f=(complex(0,X)*complex(R_2/s,X_2))/(complex(0,X)+
    complex(R_2/s,X_2));
Z_12=(-1/2)*complex(1,1/a)*(Z_lm+Z_f);
Z_1a=a^2*(2*Z_12+Z_lm);
Z=Z_1a-R_la-imult(X_la);
X_c=(-1)*imag(Z);
C=1/(314*X_c*10^-6);disp(C,'value of run capacitor(
    uF)');

Z_f=(complex(0,X)*complex(R_2/s,X_2))/(complex(0,X)+
    complex(R_2/s,X_2));
Z_b=(complex(0,X)*complex(R_2/(2-s),X_2))/(complex
    (0,X)+complex(R_2/(2-s),X_2));
Z_la=complex(R_la,X_la)-imult(10^6/(314*C));
Z_12=(1/2)*((Z_la/(a^2))-complex(R_lm,X_lm));
Z1=Z_lm+Z_f+Z_12;
Z2=Z_lm+Z_b+Z_12;
I_mf=(V_mf*Z2+V_mb*Z_12)/(Z1*Z2-(Z_12)^2);
I_mb=(V_mb*Z1+V_mf*Z_12)/(Z1*Z2-(Z_12)^2);
T=(2/157.1)*((abs(I_mf)^2*real(Z_f))-(abs(I_mb)^2*
    real(Z_b)));
I_m=I_mf+I_mb;
I_a=imult(I_mf-I_mb)/a;
I_L=I_m+I_a;
I_l=abs(I_L);    pf=1;
P_m=2*((abs(I_mf)^2*real(Z_f))-(abs(I_mb)^2*real(Z_b
    )))*(1-s);
P_L=45;
P_out=P_m-P_L;
P_in=I_l*V;
n=P_out/P_in;
disp(n,'efficiency');
```

Scilab code Exa 10.6 to calculate starting torque and atarting current motor performance

```
//to calculate starting torque and atarting current ,
   motor performance

clc;
V_a=110*complex(cosd(90),sind(90));
V_m=220*complex(cosd(0),sind(0));
R_1=3;
R_2=2.6;
X_1=2.7;
X_2=2.7;
X=110;
V_f=(1/2)*(V_m-imult(V_a));
V_b=(1/2)*(V_m+imult(V_a));
Z_f=(complex(0,X)*complex(R_2,X_2))/(complex(0,X)+
   complex(R_2,X_2));
Z_b=Z_f;
Z_ftot=complex(R_1,X_1)+Z_f;
Z_btot=complex(R_1,X_1)+Z_b;
I_f=V_f/Z_ftot;
I_b=V_b/Z_btot;
T_s=(2/157)*real(Z_f)*(abs(I_f)^2-abs(I_b)^2);disp(
   T_s,'starting torque(Nm)');
I_m=I_f+I_b;
I_a=imult(I_f-I_b);disp(abs(I_a),'starting current(A
   )');
s=0.04;

Z_f=(complex(0,X)*complex(R_2/s,X_2))/(complex(0,X)+
   complex(R_2/s,X_2));
Z_b=(complex(0,X)*complex(R_2/(2-s),X_2))/(complex
   (0,X)+complex(R_2/(2-s),X_2));
```

```
Z_ftot=complex(R_1,X_1)+Z_f;
Z_btot=complex(R_1,X_1)+Z_b;
I_f=V_f/Z_ftot;
I_b=V_b/Z_btot;
w_s=157.1;
T_s=(2/157.1)*(abs(I_f)^2*real(Z_f)-abs(I_b)^2*real(
    Z_b));disp(T_s,'starting torque(Nm)');
I_m=I_f+I_b;m=atand(imag(I_m)/real(I_m));
I_a=imult(I_f-I_b);a=atand(imag(I_a)/real(I_a));
P_m=w_s*(1-s)*T_s;
P_L=200;
P_out=P_m-P_L;
P_min=V*abs(I_m)*cosd(m);
P_ain=V*abs(I_a)*cosd(a);
P_in=P_min+P_ain;
n=P_out/P_in;
disp(n,'efficiency');

r=Z_ftot/Z_btot;      //r=V_mf/V_bf
//V_mf+V_bf=220
V_mf=220/(1+r);
V_mb=220-V_mf;
V_a=imult(V_mf-V_mb);
disp(abs(V_a),'V_a(V)');
```

Chapter 12

Motor Control by Static Power Convertors

Scilab code Exa 12.1 calculate power fed to load

```
//calculate power fed to load

clc;
V=100;
Va=(V/(sqrt(2)*%pi))*(2+1/sqrt(2));
Rd=10;
Pa=Va^2/Rd;
disp(Pa,'load power(W)');
```

Scilab code Exa 12.2 calculate firing angle value

```
//calculate firing angle value

clc;
Po=15000;
Ro=1.5;
```

```
Va=sqrt(Po*Ro);
a=acosd((Va*2*%pi/(3*sqrt(6)*V))-1);disp(a,'firing
   angle(deg)');
Ia=Va/Ro;
Ith=Ia/3;disp(Ith,'avg current through diodes(A)');
```

Scilab code Exa 12.3 calculate value of commutating capacitor

```
//calculate value of commutating capacitor

clc;
Iamax=100;
V=100;
f_max=400;
c=Iamax/(2*V*f_max);
disp(c,'value of commutating capacitor(F)');
```