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

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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.

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Chapter 2

Magnetic circuits and Induction

Scilab code Exa 2.1 calculating exciting current and corresponding flux linkages

```
1  // calculating exciting current and corresponding
      flux linkages
2
3  clc;
4  U_o=4*%pi*10^-7;
5  U_r=6000;
6  l_g=0.0006;
7  l_c=.40;
8  A_c=.04*.04;
9  B_c=1.2;
10 N=600;
11 function [i]=current(B_g)
12     i=(1/(U_o*N))*(((B_c*l_c)/U_r)+(B_g*l_g));
13 endfunction
14 disp(current(B_c),'neglecting fringing ,current(A)=')
      ;
15
16     phi=B_c*A_c;
17 disp(phi,'flux(Wb)=');
18
19 function [lmda]=flux_linkage(phi)
```

13

```
20        lmda=N*phi;
21  endfunction
22  disp(flux_linkage(phi),'flux linkages(Wb-turns)=');
23
24  A_g=(.04+l_g)^2;
25  B_g=phi/A_g;
26
27  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 magne

```
1  //Calculation of current reqd to produce flux in the
        given magnetic circuit.
2
3  clc;
4  U_o=4*%pi*10^-7;
5  U_r=4000;
6  N=600;
7  //l_c=.30;
8  //l_g=.001;
9  dia=.02;
10 phi=.5*10^-3;          //flux
11 A=(%pi/4)*dia^2;
12 function [i]=current(l_c,l_g)
13     R=((l_c/U_r)+l_g)/(U_o*A);
14     i=(phi*R)/N;
15 endfunction
16 disp(current(.30,0),'no air gap current(A)');
17 disp(current(.30,.001),'with air gap current(A)');
18
19 //B-H data
20 //H in AT/m      2500     3000     3500     4000
21 //B in T         1.55     1.59     1.6      1.615
22
```

```
23  B_g=phi/A;
24  disp(B_g,'B(T)');
25
26  H_g=B_g/U_o;
27
28  function [AT]=AT(H,l)
29      AT=H*l;
30  endfunction
31  AT_g=AT(H_g,.001);
32  disp(ceil(AT_g),'AT_g');
33
34  H_c=3000;
35  AT_c=AT(H_c,.30);
36  disp(AT_c,'AT_c');
37
38  i=(AT_g+AT_c)/N;
39  disp(i,'from magnetisation data, current(A)');
```

Scilab code Exa 2.3 Determination of mmf of the exciting coil

```
1   // Determination of mmf of the exciting coil
2
3   clc;
4   U_o=4*%pi*10^-7;
5   A1=.0001;
6   A2=.0002;
7   l1=.025*10^-2;
8   l2=.02*10^-2;
9   phi=.75*10^-3;
10  function [Re]=reluctance(l,U_r,A)
11      Re=l/(U_o*U_r*A);
12  endfunction
13
14  function [Ni]=mmf(R1,R2,R3)
15      Ni=phi*(R3+((R1*R2)/(R1+R2)));
```

```
16  endfunction
17  R_g1 = reluctance ( l1 ,1 , A1 ) ;
18  R_g2 = reluctance ( l2 ,1 , A1 ) ;
19  R_g3 = reluctance ( l2 ,1 , A2 ) ;
20  disp ( mmf ( R_g1 , R_g2 , R_g3 ) , 'when  U_r =1 ,mmf(AT) ') ;
21  L1 = l1 *2*10^3;
22  L2 = l2 *10^3;
23  R_c1 = reluctance ( L1 ,5000 , A1 ) ;
24  R_c2 = reluctance ( L1 ,5000 , A1 ) ;
25  R_c3 = reluctance ( L2 ,5000 , A2 ) ;
26  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

```
 1  // Exciting  current  calculation  needed  to  setup  reqd
         flux
 2
 3  clc ;
 4  U_o =4* % pi *10^ -7;
 5  A1 =800*10^ -6;
 6  A2 =600*10^ -6;
 7  l1 =1*10^ -3;                // air  gap  length
 8  l2 =160*10^ -3;              // length  of  central  limb
 9  l3 =400*10^ -3;              // length  of  side  limb
10  phi = .8*10^ -3;
11  N =500;
12  function  [B]= fd ( A )
13      B = phi / A ;
14  endfunction
15
16  function  [F]= mmf ( l , B )
17      F = l / B ;
18  endfunction
19  // air  gap
```

16

```
20  B_g=fd(A1);
21  F_g=mmf(l1,B_g)/U_o;disp(F_g,'F_g(AT)');
22  //central limb
23  B_c=B_g;
24  F_c=mmf(l2,B_c)/10^-3;disp(F_c,'F_c(AT)');
25  //outer limb                  flux is divided into
        half
26  B_o=fd(A2)/2;
27  F_o=mmf(l3,B_o)/(4*10^-3);disp(F_o,'F_o(AT)');
28  i=(F_g+F_c+F_o)/N;              //    total mmf/no of
        turns
29  disp(i,'exciting current(A)');
```

Scilab code Exa 2.5 determination of excitation coil mmf

```
1  // determination of excitation coil mmf
2  clc;
3  U_o=4*%pi*10^-7;
4  A1=25*10^-4;
5  A2=12.5*10^-4;
6  A3=25*10^-4;
7  l1=.5;              //length of side limb(ab+cd)
8  l2=.2;          //length of central limb(ad)
9  l3=.5;             //length of side limb(dea)
10 l4=.25*10^-3;          //length of air gap
11 phi=.75*10^-3;
12 N=500;
13 function [B]=fd(A)
14     B=phi/A;
15     endfunction
16 function [F]=flux(B,l)
17     F=B*l/(U_o);
18     endfunction
19 function [f]=fl(H,l)
20 f=H*l;
```

```
21  endfunction
22  B_abcd=fd(A1);
23  F_bc=flux(B_abcd,l4);
24  disp(B_abcd,'B_abcd(T)');
25  H_ab=200;                        //for cast iron for
        B=0.3
26  F_abcd=fl(H_ab,l1);
27  F_ad=F_abcd+F_bc;
28  H_ad=F_ad/l2;
29  disp(H_ad,'H_ad(AT/m)');
30  B_ad=1.04                        //for cast iron for
        H=800
31  phi_ad=B_ad*A2;
32  phi_dea=phi+phi_ad;
33  B_dea=phi_dea/A3;
34  H_dea=500                        //for cast iron
        for B=.82
35  F_dea=H_dea*l3;
36  F=F_dea+F_ad;
37  disp(F,'reqd mmf(AT)');
```

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

```
1  //determination of self and mutual inductance b/w 2
      coils
2
3  clc;
4  U_o=4*%pi*10^-7;
5  U_r=1600;
6  A1=4*10^-4;
7  A2=4*10^-4;
8  A0=2*10^-4;
9  N1=500;
10 N2=1000;
11
```

```
12  l1 =.01*((6+0.5+1)*2+(4+2));
13  l2 =.01*((3+0.5+1)*2+(4+2));
14  l0 =.01*(4+2);
15  function [R]=reluc(l,A)
16      R=l/(U_o*U_r*A);
17  endfunction
18  R1=reluc(l1,A1);
19  R2=reluc(l2,A2);
20  R0=reluc(l0,A0);
21
22  function [re]=re(r0,r1,r2)
23      re=r0+((r1*r2)/(r1+r2));
24  endfunction
25
26  disp('coil 1 excited with 1A');
27  R_1=re(R1,R0,R2);
28  phi1=N1/R_1;
29  phi2=phi1*R0/(R0+R2);
30  L11=N1*phi1;disp(L11,'self inductance(H)');
31  M21=N2*phi2;disp(M21,'mutual inductance(H)');
32  disp('coil 2 excited with 1A');
33  R_2=re(R2,R0,R1);
34  phi2=N2/R_2;
35  L22=N2*phi2;disp(L22,'self inductance(H)');
36  M12=M21;disp(M12,'mutual inductance(H)');
```

Scilab code Exa 2.8 determination of Rc Rg L Wf

```
1  //determination of R_c,R_g,L,W_f
2
3  clc;
4  U_o=4*%pi*10^-7;
5  U_r=6000;
6  l_g=0.0006;
7  l_c=.40;
```

```
8  A_c =.04*.04;
9  B_c =1.2;
10 N=600;
11 function [i]= current ( B_g )
12     i =(1/( U_o * N ))*((( B_c * l_c )/ U_r )+( B_g * l_g ));
13 endfunction
14 disp ( current ( B_c ), ' n e g l e c t i n g  f r i n g i n g , c u r r e n t (A)=' )
     ;
15
16     phi = B_c * A_c ;
17 disp ( phi , ' f l u x (Wb)=' ) ;
18
19 function [lmda]= flux_linkage ( phi )
20     lmda = N * phi ;
21 endfunction
22 disp ( flux_linkage ( phi ), ' f l u x  l i n k a g e s (Wb−t u r n s )=' ) ;
23
24 function [R]= reluc (l,U,A)
25     R=l /( U_o * U * A );
26 endfunction
27 R_c = reluc ( l_c , U_r , A_c ); disp ( R_c , 'R_c=' ) ;
28 R_g = reluc ( l_g ,1 , A_c ); disp ( R_g , 'R_g=' ) ;
29
30 L=N^2/( R_c + R_g );
31 disp (L, ' c o i l  i n d u c t a n c e (H) ' ) ;
32
33 W_f =( N * phi )^2/(2* L );
34 disp ( W_f , ' e n e r g y  s t o r e d  i n  t h e  m a g n e t i c  f i e l d ( J ) ' ) ;
```

Scilab code Exa 2.9 calculation of hysterisis and eddy current losses

```
1 // c a l c u l a t i o n  o f  h y s t e r i s i s  a n d  e d d y  c u r r e n t  l o s s e s
2
3 clc ;
4 P1 =1500;
```

```
 5  f1=50;
 6  P2=3000;
 7  f2=75;
 8  A=[1 50;1 75];                        //P/f=A+B*f
 9  B=[30;40];
10  v=A\B;
11
12  disp('at 50Hz');
13  P_h=v(1)*f1;disp(P_h,'hysterisis loss(W)');
14  P_e=v(2)*f1^2;disp(P_e,'eddy current loss(W)');
15
16  disp('at 75Hz');
17  P_h=v(1)*f2;disp(P_h,'hysterisis loss(W)');
18  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 magnet

```
1  // To determine no load power factor ,core loss
      current and magnetising current
2  //  and no load ckt parameters of transformer
3
4  clc ;
5  Pi =50;
6  V1 =230;
7  Io =2;
8  pf = Pi /( V1 * Io ) ; disp ( pf , 'no load power factor ') ;
9  Im = Io * sind ( acosd ( pf ) ) ; disp ( Im , 'magnetising current (A
      ) ') ;
10 Ii = Io * pf ; disp ( Ii , 'core loss current (A) ') ;
11 Gi = Pi / V1 ^2; disp ( Gi , 'Gi ( mho ) ') ;
12 Bm = Im / V1 ; disp ( Bm , 'Bm ( mho ) ') ;
```

Scilab code Exa 3.2 To calculate no load current and its pf and no load power draw

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

22

```
2
3  clc;
4  E=200;
5  f=50;
6  N1=150;              // no of turns
7  b1=.1;
8  b2=.05;
9  phi_max=E/(4.44*f*N1);
10 disp(phi_max,'flux (Wb)');
11 B_max=phi_max/(b1*b2);
12 disp(B_max,'B_max(T)');
13
14 H_max=250;           //According to B_max, H_max is 250
      AT/m
15 l_c=.2*(3.0+3.5);    //length of core
16 AT_max=H_max*l_c;
17 disp(AT_max,'AT_max');
18 T_max=N1;
19 I_mmax=AT_max/T_max;
20 I_mrms=I_mmax/2^.5;
21 disp(I_mrms,'I_mrms(A)');
22
23 v=2*(20*10*5)+2*(45*10*5);
24
25 d=.0079;             //density of core material
26 w=v*d;
27
28 cl=3;                //core loss/kg
29 closs=w*cl;
30 disp(closs,'core loss(W)');
31 I_i=closs/E;
32 disp(I_i,'I_i(A)');
33 function [r,pff]=rect2polar(x,y)
34     r=sqrt(x^2+y^2);
35     pff=cosd(atand(y/x));
36 endfunction
37 [I_o,pf]=rect2polar(I_i,-I_mmax);
38 disp(I_o,'no load current(A)');
```

23

```
39 disp(pf,'no load power factor');
```

Scilab code Exa 3.3 To calculate primary and scondary side impedences current and

```
1 // To calculate primary and scondary side impedences
     , current and their pf and real power
2 // and calculate terminal voltage
3
4 clc;
5 N_1=150;
6 N_2=75;
7
8 a=N_1/N_2;
9
10 Z_2=[5,30];                   // polar (magnitude , phase
     diff)
11 disp(Z_2,'secondary impedence(ohm)');
12 Z_1=[a^2*Z_2(1),Z_2(2)];
13 disp(Z_1,'primary impedence(ohm)');
14
15 V_1=[200,0];                  // polar (magnitde , phase
     diff)
16 V_2=[V_1(1)/a,V_1(2)];
17 disp(V_2,'secondary terminal voltage(V)');
18
19 I_2(1)=V_2(1)/Z_2(1);
20 I_2(2)=V_2(2)-Z_2(2);
21 disp(I_2,'I_2=');
22 pf=cosd(I_2(2));
23 disp(pf,'pf lagging=');
24
25 I_1(1)=I_2(1)/a;
26 I_1(2)=I_2(2);
27 disp(I_1,'I_1(A)');
28 pf=cosd(I_1(2));
```

```
29  disp(pf,'pf lagging=');
30
31  P_2=V_2(1)*I_2(1)*cosd(I_2(2));
32  disp(P_2,'secondary power output(W)=');
33  //P_1=primary power output
34  P_1=P_2                              //as the
        transormer is lossless
35  disp(P_1,'primary power output(W)=');
```

Scilab code Exa 3.4 To calculate primary current and its pf

```
1  // To calculate primary current and its pf
2
3  clc;
4
5  function [x,y]=polar2rect(r,theta)
6      x=r*cosd(theta);
7      y=r*sind(theta);
8  endfunction
9
10  function [r,theta]=rect2polar(x,y)
11      r=sqrt(x^2+y^2);
12      theta=atand(y/x);
13  endfunction
14
15  I_2=[10 -30];
16  [I_2r(1),I_2r(2)]=polar2rect(I_2(1),I_2(2));
17
18  I_0=[1.62 -71.5];
19  [I_0r(1),I_0r(2)]=polar2rect(I_0(1),I_0(2));
20
21  I_1r=I_0r+I_2r;
22
23  [I_1(1),I_1(2)]=rect2polar(I_1r(1),I_1r(2));
24  disp(I_1(1),'primary current(A)=');
```

```
25 pf=cosd(I_1(2));
26 disp(pf,'power factor=');
```

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

```
1 // Equivalent circuit referred to(i)HV side (ii)LV
     side
2
3 clc;
4
5 N_1=2000;
6 N_2=200;
7
8 a=N_1/N_2;
9
10 Z_2=complex(.004,.005);              //low voltage
     impedence
11 Z_2hv=a^2*Z_2;
12 disp(Z_2hv,'Z_2 referred to hv side(ohm)');
                              //when referred to hv side
13
14 Y_0=complex(.002,-.015);             //shunt branch
     admittance
15 Y_0hv=Y_0/a^2;
16 disp(Y_0hv,'Y_0 referred to hv side(mho)');
17
18 Z_1=complex(.42,.52);                     //low voltage
     impedence
19 Z_1lv=Z_1/a^2;
20 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 lo

```scilab
1  // To find the voltage at the load end of the
       transformer when load is drawing transformer
       current
2
3  clc;
4
5  I=20/2;                          //rated load current(hv
       side)
6
7  Z1=[.25,1.4];                          //impedence of
       feeder    (REAL,IMAGINERY)
8  Z2=[.82,1.02];                          //impedence of
       transformer     (REAL,IMAGINERY)
9
10 Z=Z1+Z2;
11 disp(Z,'Z(ohm)');
12
13 pf=.8;
14 phi=acosd(pf);
15
16 //from phasor diagram
17
18 R=Z(1);
19 X=Z(2);
20 AF=I*X*cosd(phi);
21 FE=I*R*sind(phi);
22 AE=AF-FE;
23 OA=2000;
24 OE=sqrt(OA^2-AE^2);
25
26 BD=I*R*cosd(phi);
27 DE=I*X*sind(phi);
28 BE=BD+DE;
29 V1=OE;    disp(V1,'V1(V)');
30 V2=V1-BE;    disp(V2,'V2(V)');
31
32 loadvol=V2/10;                          //referred to
       LV side
```

```
33  disp ( loadvol , 'load voltage (V) ') ;
```

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

```
 1  // Approx  equivalent  ckt  referred  to  hv  and  lv  sides
        resp ,
 2
 3  clc ;
 4  //open  ckt  test  data  with  HV  side  open
 5  ocv =200;
 6  oci =4;
 7  ocp =120;
 8  // short  ckt  test  data  with  LV  side  open
 9  scv =60;
10  sci =10;
11  scp =300;
12  //OC  test (LV  side )
13  Y_o = oci / ocv ;      disp (Y_o , 'Y_o (mho) ') ;
14  G_i = ocp / ocv ^2;   disp (G_i , 'G_i (mho) ') ;
15  B_m = sqrt (Y_o ^2 - G_i ^2) ;    disp (B_m , 'B_m (mho) ') ;
16  //SC  test (HV  side )
17  Z = scv / sci ;         disp (Z , 'Z(ohm) ') ;
18  R = scp / sci ^2;      disp (R , 'R(ohm) ') ;
19  X = sqrt (Z ^2 - R ^2) ;    disp (X , 'X(ohm) ') ;
20
21  N_H =2000;
22  N_L =200;
23  a = N_H / N_L ;                            //
        transformation  ratio
24
25  // Equivalent  ckt  referred  to  HV  side
26  G_iHV = G_i / a ^2;           disp (G_iHV , 'G_i (HV) mho ') ;
27  B_mHV = B_m / a ^2;           disp (B_mHV , 'B_m (HV) mho ') ;
28
29  // Equivalent  ckt  referred  to  LV  side
```

```
30  RLV=R/a^2;              disp(RLV,'R(LV)ohm');
31  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

```
1  // to calculate (a)open ckt current,power and pf
      when LV excited at rated voltage
2  // (b) voltage at which HV side is excited, ip power
      and its pf
3
4  clc;
5  r=150000;                               //
      rating(VA)
6  V1=2400;
7  V2=240;
8  a=V1/V2;
9
10 R_1=.2;
11 X_1=.45;
12 R_i=10000;
13 R_2=2*10^-3;
14 X_2=4.5*10^-3;
15 X_m=1600;
16 //Referring the shunt parameters to LV side
17 R_iLV=R_i/a^2;
18 X_mLV=X_m/a^2;
19 I_oLV=[V2/100 V2/16];
20 I_o=sqrt(I_oLV(1)^2+I_oLV(2)^2);   disp(I_o,'I_o(A)
      ');
21 pf=cosd(atand(I_oLV(2)/I_oLV(1)));   disp(pf,'pf');
22 //equivalent series parameters referred to HVside
23 R=R_1+R_2*a^2;
24 X=X_1+X_2*a^2;
25 Z=complex(R,X);    disp(Z,'Z(ohm)');
26 z=[R X];
```

29

```
27  I_flHV=r/V1;
28  V_scHV=I_flHV*sqrt(R^2+X^2);
29  P_sc=I_flHV^2*R;        disp(P_sc,'P_sc(W)');
30  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 H

```
1   //To find  exciting  current  and  expess  impedence  in
        pu  in  both  HV  and  LV  sides
2
3   clc;
4
5   V_BHV=2000;
6   I_BHV=10;
7   Z_BHV=V_BHV/I_BHV;
8
9   V_BLV=200;
10  I_BLV=100;
11  Z_BLV=V_BLV/I_BLV;
12
13  I_o=3;
14  a=V_BHV/V_BLV;
15
16  I_oLV=I_o/100;      disp(I_oLV,'I_o(LV)pu=');
17  I_oHV=I_o/(a*10);       disp(I_oHV,'I_o(HV)pu=');
18
19  Z=complex(8.2,10.2);
20  ZHV=Z/Z_BHV;       disp(ZHV,'Z(HV)pu=');
21  z=Z/a^2;
22  ZLV=z/Z_BLV;       disp(ZLV,'Z(LV)pu=');
```

Scilab code Exa 3.11 o calculate efficiency of transformer

```
1  // To calculate efficiency of transformer
2
3  clc;
4
5  V_2=200;
6  I_2=100;
7  pf=.8;
8  P_o=V_2*I_2*pf;                //power output
9
10 P_i=120;
11 P_c=300;
12 k=1;
13 P_L=P_i+k^2*P_c;               //total losses
14
15 n=1-(P_L/(P_o+P_L));         disp(n*100,'n(%)');
16
17 K=sqrt(P_i/P_c);               //max efficiency
18
19 n_max=1-(2*P_i/(P_o*K+2*P_i));          //pf=.8
20 disp(n_max*100,'n_max(%)');
```

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

```
1  // Comparing all-day efficiencies for diff given
     load cycles
2
3  clc;
4
5  r=15;                  // kva rating
6  n_max=.98;
7  pf=1;
8  P_o=20;
9  P_i=r*(1-n_max)/2;
10 k=r*pf/P_o;
11 P_c=P_i/(k^2);
```

```
12  function  [W_o,W_in]=power(P_o,h)
13      k=P_o/20;
14      P_c=P_i*P_o/r;
15      W_o=P_o*h;
16      W_in=(P_o+P_i+(k^2)*P_c)*h;
17  endfunction
18
19  //(a)full  load  of  20kva  12hrs/day  and  no  load  rest
        of  the  day
20  a=[20  12];
21  [W_oa(1),W_ina(1)]=power(a(1),a(2));
22  aa=[0  12];
23  [W_oa(2),W_ina(2)]=power(aa(1),aa(2));
24  disp(W_oa,'W_o(kWh)  for  a');
25  disp(W_ina,'W_in(kWh)  for  a');
26  n_ada=sum(W_oa)/sum(W_ina);      disp(n_ada*100,'
        n_allday(a)  in  %age');
27
28  //(b)full  load  of  20kva  4hrs/day  and  .4  of  full  load
        rest  of  the  day
29  b=[20  4];
30  [W_ob(1),W_inb(1)]=power(b(1),b(2));
31  bb=[8  20];
32  [W_ob(2),W_inb(2)]=power(bb(1),bb(2));
33  disp(W_ob,'W_o(kWh)  for  b');
34  disp(W_inb,'W_in(kWh)  for  b');
35  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 a

```
1  // To  calculate  volatage  regulation ,  volatage  at
        load  terminals  and  operating  efficiency
2
3  clc;
```

```
4  S=20*1000;
5  V1=200;
6  V2=2000;
7  I1=S/V1;
8  I2=S/V2;
9  Rh=3;
10 Xh=5.2;
11 pf=0.8;
12 phi=acosd(pf);
13 Vha=V2+I2*(Rh*cosd(phi)+Xh*sind(phi));      //
      lagging
14 Vrega=(Vha-V2)*100/V2;      disp(Vrega,'vol-reg
      lagging(%)');
15 Vhb=V2+I2*(Rh*cosd(phi)-Xh*sind(phi));      //
      leading
16 Vregb=(Vhb-V2)*100/V2;      disp(Vregb,'vol-reg
      leading(%)');
17
18 V11=V2-I2*(Rh*cosd(phi)+Xh*sind(phi));
19 v1=V11/I2;          disp(v1,'V_L(V)');
20 ploss=120+10*10*3;
21 pop=v1*I1*cosd(phi);
22 eff=(1-(ploss/(ploss+pop)))*100;
23 disp(eff,'eff(%)');
```

Scilab code Exa 3.15 To determine voltage regulation and efficiency

```
1 // To determine voltage regulation and efficiency
2
3 clc;
4
5 r=150*1000;                     //rating in va
6 v1=2400;
7 v2=240;
8 a=v2/v1;
```

```
9  R_hv=.2+.002/a^2;
10  X_hv=.45+.0045/a^2;
11  I_2fl=r/v2;
12  pf=0.8            //lagging
13  phi=acosd(pf);
14  I_2=I_2fl*a;
15  vd=I_2*(R_hv*cosd(phi)+X_hv*sind(phi));
16  V2=v1;
17  vr=(vd/V2)*100;          disp(vr,'vol reg(%)');
18  V1=v1+vd;
19  P_out=r*pf;
20  P_c=(I_2^2)*R_hv;        //copper loss
21  P_i=(V1^2)/10000;
22  P_L=P_c+P_i;
23  n=P_out/(P_out+P_L);       disp(n*100,'eff(%)');
24
25  I_o(1)=V1/(10*1000);
26  I_o(2)=-V1/(1.6*1000);       //inductive effect
27  I2(1)=I_2*(cosd(phi));
28  I2(2)=I_2*(-sind(phi));
29  I_1=I_o+I2;
30  b=sqrt(I_1(1)^2+I_1(2)^2);
31  disp(b,'I_1(A)');
32  pff=cosd(atand(I_1(2)/I_1(1)));
33  disp(pff,'pf');
```

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

```
1  // to calculate  voltage  ratings ,kva  ratings  and
       efficieny  of  autotransformer
2
3  clc;
4
5  AB=200;
6  BC=2000;
```

```
7  V_1=BC;           disp(V_1,'V_1(V)');
8  V_2=AB+BC;        disp(V_2,'V_2(V)');
9  r=20000;                  //rating of transformer
10 I_2=r/AB;
11 I_1=I_2+10;
12 rr=V_2*I_2/1000;          //kva rating of
       autotransformer
13 disp(rr,'kva rating');
14 ri=V_1*(I_1-I_2)/1000;    //kva inductive
15 rc=rr-ri;
16 disp(ri,'kva transferred inductively');
17 disp(rc,'kva transferred conductively');
18 W_c=120;                  //core loss
19 W_cu=300;                 //cu loss
20 W_t=W_c+W_cu;             //total loss
21 pf=0.8;
22 W=V_2*I_2*pf;             //full load output
23 n=1-(W_t/W);
24 disp(n*100,'eff(%)');
```

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

```
1  // To determine the rating and full load efficiency
     of autotransformer
2
3  clc;
4  //when used as transformer
5  v1=240;
6  v2=120;
7  r=12000;
8  I1=r/v1;
9  I2=r/v2;
10
11 //when connected as autotransformer
12 V1=240;
```

```
13  V2=v1+v2;
14  rr=I2*V2;                 disp(rr,'rating of
        autotransformer(va)');
15
16  pf=1;
17  P_o=r*pf;                 //output power
18  n=.962                    //efficiency at upf
19  P_L=P_o*(1-n)/n;
20
21  pff=.85                   //if pf=.85
22  Po=rr*pff;
23  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

```
1  // To calculate sec. line voltage, line current and
       output va
2
3  clc;
4
5  disp('(a)Y/D conn');
6  V_LY=6600;
7  V_PY=V_LY/sqrt(3);
8  a=12;
9  V_PD=V_PY/a;
10 V_LD=V_PD;     disp(V_LD,'sec line voltage(V)');
11
12 I_PY=10;
13 I_PD=I_PY*a;
14 I_LD=I_PD*sqrt(3);    disp(I_LD,'sec. line current(A
       )');
15 r=sqrt(3)*V_LD*I_LD;    disp(r,'output rating(va)');
16
17 disp('(b)D/Y conn');
```

```
18  I_LD=10;
19  I_PD=I_LD/sqrt(3);
20  I_LY=I_PD*a;              disp(I_LY,'sec. line current(A)'
        );
21  V_PD=6600;
22  V_PY=V_PD/a;
23  V_LY=V_PY*sqrt(3);       disp(V_LY,'sec line voltage(V)
        ');
24  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

```
1  // To compute all the currents and voltages in all
        windings of Y/D transformer
2
3  clc;
4
5  S=complex(500,100);           //load is 500MW and 100
        MVar
6  s=abs(S);
7  r=s/3;          //MVA rating of each single ph
        transformer
8
9  V1=22;          //D side
10 V2=345;          //Y side
11 a=V2/(sqrt(3)*V1);          //voltage rating of each
        single phase
12 disp('Y side');
13 V_A=(V2/sqrt(3))*complex(cosd(0),sind(0));
14 V_B=(V2/sqrt(3))*complex(cosd(-120),sind(-120));
15 V_C=(V2/sqrt(3))*complex(cosd(-240),sind(-240));
16
17 V_AB=V_A-V_B;     disp(V_AB,'V_AB(V)');
18 V_BC=V_B-V_C;     disp(V_BC,'V_BC(V)');
19 V_CA=V_C-V_A;     disp(V_CA,'V_CA(V)');
```

```
20
21  IA=S/(3*V_A);      disp(IA,'IA(A)');
22  IB=S/(3*V_B);      disp(IB,'IB(A)');
23  IC=S/(3*V_C);      disp(IC,'IC(A)');
24  disp('D side');
25  V_ab=V_A/a;      disp(V_ab,'V_ab(V)');
26  V_bc=V_B/a;      disp(V_bc,'V_bc(V)');
27  V_ca=V_C/a;      disp(V_ca,'V_ca(V)');
28
29  I_ab=a*IA;
30  I_bc=a*IB;
31  I_ca=a*IC;
32  Ia=I_ab-I_bc;      disp(Ia,'Ia(A)');
33  Ib=I_bc-I_ca;      disp(Ib,'Ib(A)');
34  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 tra

```
1  // to find the load voltage when it draws rated
      current from transformer
2
3  clc;
4  // here pu method is used
5  r=20;           //kva rating of three 1-ph transformer
6  MVA_B=r*3/1000;
7  v2=2*sqrt(3);         //in kv voltage base on hv side
8  v1=.2;           //in kv voltage base on lv side
9
10  z1=complex(.0004,.0015);         //feeder impedence
11  Z1=z1*MVA_B/v1^2;         // lv line(pu)
12  z2=complex(.13,.95);         //load impedence
13  Z2=z2*MVA_B/v2^2;         // hv line(pu)
14  z_T=complex(.82,1.02);
15  ZTY=z_T*MVA_B/v2^2;         // star side(pu)
16
```

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

Scilab code Exa 3.21 to calculate fault currentin feeder lines primary and seconda

```
1  // to  calculate  fault  currentin  feeder  lines , primary
        and  secondary  lines  of  receiving  end
        transformers
2
3  clc ;
4
5  r =60;              // kva  rating  of  3 - ph  common  base
6  s =200;             // kva  rating  of  3ph  transformer
7  // sending  end
8  X_Tse =.06* r / s ;    //.06=  reactance  of  transformer
        based  on  its  own  rating
9  // in  2  kv  feeder
10  V_B =2000/ sqrt (3) ;      // line  to  neutral
11  I_B = r *1000/( sqrt (3) *2000) ;
12  Z_B = V_B / I_B ;
13  X_feeder =0.7/ Z_B ;            // feeder  reactance =0.7
14  // receiving  end
15  X_Tre =0.0051;
16  X_tot = X_Tse + X_feeder + X_Tre ;
17  V_se =20/20;
18  I_fc = V_se / X_tot ;    // feeder  current
19
20  I_f = I_fc * I_B ;       disp ( I_f , ' current  in  2kv  feeder (A) '
        ) ;
```

```
21  I_t1=I_f/sqrt(3);       disp(I_t1,'current in 2kv
        winding of transformer(A)');
22  I_t2=I_t1*10;       disp(I_t2,'current in 200kv winding
         of transformer(A)');
23  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

```
1  // To calculate voltage and kva rating of 1−ph
       transformer
2
3  clc;
4
5  V_p=33;       //primary side voltage(V)
6  V_s=11;       //secondary side voltage(V)
7  V_p1=V_p/sqrt(3);       //per ph primary side voltage(V
       )
8  V_p2=V_s/sqrt(3);       //per ph secondary side voltage
       (V)
9
10  r=6000;       //kva rating 3−ph
11  s=r/3;       //per phase
12  disp('Y/Y conn');
13  disp(V_p1,'primary side ph voltage(V)');
14  disp(V_p2,'secondary side ph voltage(V)');
15  disp(s,'kva rating of transformer');
16
17  disp('Y/D conn');
18  disp(V_p1,'primary side ph voltage(V)');
19  disp(V_s,'secondary side ph voltage(V)');
20  disp(s,'kva rating of transformer');
21
22  disp('D/Y conn');
23  disp(V_p,'primary side ph voltage(V)');
```

```
24  disp ( V_p2 , ' secondary side ph voltage (V) ');
25  disp ( s , 'kva rating of transformer ');
26
27  disp ( 'D/D conn ');
28  disp ( V_p , 'primary side ph voltage (V) ');
29  disp ( V_s , 'secondary side ph voltage (V) ');
30  disp ( s , 'kva rating of transformer ');
```

Scilab code Exa 3.23 to calculate reactance in ohms line voltage kva rating series

```
 1  // to calculate (a) reactance in ohms (b) line voltage ,
       kva rating , series reactance for Y/Y    and Y/D
       conn
 2
 3  clc ;
 4  Xpu =0.12;      // of 1-ph transformer
 5
 6  function [X]=Xohm (kv , MVA )
 7      X=( Xpu * kv ^2)/ MVA ;
 8  endfunction
 9
10  disp ( '(a) ');
11  MVAa =75*10^ -3;
12  Vhv =6.6;
13  Vlv = .4;
14  Xhv = Xohm ( Vhv , MVAa );       disp ( Xhv , 'X( ohm ) of hv side ')
        ;
15  Xlv = Xohm ( Vlv , MVAa );       disp ( Xlv , 'X( ohm ) of lv side ')
        ;
16
17  disp ( '(b) ');
18  disp ( 'Y/Y ');
19  MVAb = MVAa *3;
20  Vhv =6.6* sqrt (3);      disp ( Vhv , 'V_hv (kV) ');
21  Vlv = .4* sqrt (3);       disp ( Vlv , 'V_lv (kV) ');
```

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```
22  Xhv=Xohm(Vhv,MVAb);        disp(Xhv,'X(ohm) of hv side')
        ;
23  Xlv=Xohm(Vlv,MVAb);        disp(Xlv,'X(ohm) of lv side')
        ;
24
25  disp('Y/D');
26  MVAb=MVAa*3;
27  Vhv=6.6*sqrt(3);    disp(Vhv,'V_hv(kV)');
28  Vlv=.4;                     disp(Vlv,'V_lv(kV)');
29  Xhv=Xohm(Vhv,MVAb);        disp(Xhv,'X(ohm) of hv side')
        ;
30  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

```
1  //find how 2 transformers connected in parallel
        share the load
2
3  clc;
4  Z1=complex(.012,.06);
5  Z2=2*complex(.014,.045);
6  Z=Z1+Z2;
7  r=800;              //kva rating
8  pf=.8;
9  S_L=r*(complex(pf,-1*sind(acosd(pf))));
10 S_1=S_L*Z2/Z;disp(S_1,'load by first transformer(kVA
        )');
11 S_2=S_L*Z1/Z;disp(S_2,'load by second transformer(
        kVA)');
12
13 S_2rated=300;
14 S_Lmax=S_2rated*abs(Z)/abs(Z1);
15 disp(S_Lmax,'max load by both transformer(kVA)');
16
```

```
17  r1 =600;           // kva
18  V =440;
19  Z1actual = Z1 * V /( r1 *1000/ V );
20  Z2actual = Z2 * V /( r1 *1000/ V );
21  Zactual = Z1actual + Z2actual ;
22  Z_Lact = V ^2/( S_L *1000);
23
24  V1 =445;
25  I1 =( V1 * Z2actual -10* Z_Lact )/( Z1actual * Z2actual + Z_Lact
       * Zactual );
26  I2 =( V1 * -1* Z1actual -10* Z_Lact )/( Z1actual * Z2actual +
       Z_Lact * Zactual );
27  S1 = V * I1 /1000;      disp ( S1 , 'kVA of first transformer ')
       ;
28  S2 = V * I2 /1000;      disp ( S2 , 'kVA of second transformer '
       );
29  Pout = abs ( S1 )* cosd ( atand ( imag ( S1 )/ real ( S1 )))+ abs ( S2 )*
       cosd ( atand ( imag ( S2 )/ real ( S2 )));
30  disp ( Pout , 'total output power (kW) ');
```

Scilab code Exa 3.25 find pu value of the equivalent ckt steady state short ckt cu

```
1  // find pu value of the equivalent ckt , steady state
       short ckt current and voltages
2
3  clc ;
4  r =5;          // MVA rating
5  V_Bp =6.35;      // for primary
6  I_Bp = r *1000/ V_Bp ;
7  V_Bs =1.91;      // for secondary
8  I_Bs = r *1000/ V_Bs ;
9  // from resp tests
10  V1 = .0787;
11  I1 = .5;
12  V2 = .1417;
```

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```
13  I2 =.5;
14  V3 =.1212;
15  I3 =.5;
16  X12 = V1 / I1 ;
17  X13 = V2 / I2 ;
18  X23 = V3 / I3 ;
19  X1 = I1 *( X12 + X13 - X23 ) ;
20  X2 = I2 *( X23 + X12 - X13 ) ;
21  X3 = I3 *( X13 + X23 - X12 ) ;
22  disp ( X1 , 'X1 ( pu ) ') ;
23  disp ( X2 , 'X2 ( pu ) ') ;
24  disp ( X3 , 'X3 ( pu ) ') ;
25
26  V1 =1;
27  I_sc = V1 / X13 ;
28  I_scp = I_sc * I_Bp ;      disp ( I_scp , 'sc  current  primary
        side (A) ') ;
29  I_sct = I_sc * r *1000*1000/(400/ sqrt (3) ) ;    disp ( I_sct ,
        'sc  current  tertiary  side (A) ') ;
30  V_A = I_sc * X3 ;
31  V_Aact = V_A *1.91* sqrt (3) ;
32  disp ( V_Aact , 'V_A ( actual )  line  to  line ( kV ) ') ;
```

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

```
1  // to  calculate  line  currents  of  3  ph  side
2
3  clc ;
4  N1 =6600;
5  N2 =100;
6  a = N1 / N2 ;
7  b =( sqrt (3) /2) * a ;
8  P =400;      // kW
9  pfa =.707;
10 pfb =1;
```

```
11  V =100;
12  Ia=P*1000/(V*pfa);
13  Ib=P*2*1000/(V*pfb);
14  I_A=Ia/b;disp(I_A,'I_A(A)');
15  I_BC=Ib/a;
16  I_B=I_BC-49.5*complex(pfa,pfa);    disp(abs(I_B),'
        I_B(A)');
17  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

```
1  //to calculate magnitude and phase of secondary
        current
2
3  clc;
4  X1=505;      //uohm
5  X2=551;      //uohm
6  R1=109;      //uohm
7  R2=102;      //uohm
8  Xm=256;      //mohm
9  I1=250;      //A
10 I22=complex(0,Xm*1000)*I1/(complex(R1,X2+Xm*1000));
11 N1=250;
12 N2=5;
13 I2=I22*(N2/N1);
14 disp(abs(I2),'current magnitude(A)');
15 disp(atand(imag(I2)/real(I2)),'phase(degree)');
16 disp('now Rb is introduced in series');
17 Rbb=200;     //uohm
18 Rb=(N2/N1)^2*Rbb;
19 I22=complex(0,Xm*1000)*I1/(complex((R1+Rb),X2+Xm
        *1000));
20 I2=I22*(N2/N1);
21 disp(abs(I2),'current magnitude(A)');
```

```
22 disp(atand(imag(I2)/real(I2)),'phase(degree)');
23 disp('no chnage as Rb is negligible');
```

Scilab code Exa 3.28 to calculate sec voltage magnitude and ph

```
1 //to calculate sec voltage magnitude and ph
2
3 clc;
4 a=6000/100;     //turn ratio
5 R1=780;
6 R2=907;
7 X1=975;
8 X2=1075;
9 Xm=443*1000;
10 disp('sec open');
11 //Zb=inf;
12 V1=6500;
13 V22=complex(0,Xm)*V1/complex(R1,Xm);
14 V2=V22/a;
15 disp(abs(V2),'voltage magnitude(V)');
16 disp(atand(imag(V2)/real(V2)),'phase(deg)');
17
18 disp('when Zb=Rb');
19 Rb=1;
20 Rbb=Rb*a^2;
21 Zm=complex(0,Xm/1000)*Rbb/complex(0,Xm/1000)+Rbb;
22 R=complex(R1/1000,X1/1000)+Zm;
23 Vm=Zm*V1/R;
24 V2=Vm/a;
25 disp(abs(V2),'voltage magnitude(V)');
26 disp(atand(imag(V2)/real(V2)),'phase(deg)');
27
28 disp('when Zb=jXb');
29 Rb=complex(0,1);
30 Rbb=Rb*a^2;
```

```
31  Zm=complex(0,Xm/1000)*Rbb/complex(0,Xm/1000)+Rbb;
32  R=complex(R1/1000,X1/1000)+Zm;
33  Vm=Zm*V1/R;
34  V2=Vm/a;
35  disp(abs(V2),'voltage magnitude(V)');
36  disp(atand(imag(V2)/real(V2)),'phase(deg)');
```

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

```
1  //to calculate L1 and L2 and coupling cofficient
2
3  clc;
4  a=10;
5  V_p=200;
6  I_p=4;
7  Xm=V_p/I_p;
8  f=50;
9  L1=Xm/(2*%pi*f);disp(L1,'L1(H)');
10  V_s=1950;
11  w_max=V_s/(sqrt(2)*%pi*f);
12  M=w_max/(sqrt(2)*I_p);
13
14  v_s=2000;
15  i_s=.41;
16  w_max=sqrt(2)*i_s*M;
17  E1=sqrt(2)*%pi*f*w_max;
18  L2=v_s/(sqrt(2)*%pi*f*sqrt(2)*i_s);disp(L2,'L2(H)');
19  k=M/(sqrt(L1)*sqrt(L2));disp(k,'coupling coeff');
```

Scilab code Exa 3.30 to calculate leakage inductance magnetisisng inductance mutua

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

```
 2
 3  clc;
 4  V1=2400;
 5  V2=240;
 6  a=V1/V2;
 7  R1=.2;
 8  X1=.45;
 9  Rl=10000;
10  R2=2*10^-3;
11  X2=4.5*10^-3;
12  Xm=1600;
13  f=50;
14  l1=X1/(2*%pi*f);disp(l1,'leakage inductance ie l1(H)
       ');
15  l2=X2/(2*%pi*f);disp(l2,'l2(H)');
16  Lm1=Xm/(2*%pi*f);disp(Lm1,'magnetising inductance(H)
       ');
17  L1=Lm1+l1;disp(L1,'self-inductance ie L1(H)');
18  M=Lm1/a;
19  L2=l2+M/a;disp(L2,'L2(H)');
20  k=M/sqrt(L1*L2);disp(k,'coupling factor');
```

Scilab code Exa 3.31 to calculate percentage voltage reg and efficiency

```
 1  //to calculate %voltage reg and efficiency
 2
 3  clc;
 4  P=500000;
 5  V1=2200;
 6  V2=1100;
 7  V0=110;
 8  I0=10;
 9  P0=400;
10  Y0=I0/V0;
11  Gi=P0/(V0^2);
```

```
12  Bm=sqrt(Y0^2-Gi^2);
13  Vsc=90;
14  Isc=20.5;
15  Psc=808;
16  Z=Vsc/Isc;
17  R=Psc/Isc^2;
18  X=sqrt(Z^2-R^2);
19  TR=V1/V2;
20  Gi_HV=Gi/TR^2;
21  Bm_HV=Bm/TR^2;
22  R_LV=R/TR^2;
23  X_LV=X/TR^2;
24  I2=P/V2;
25  pf=.8;
26  Th=acos(pf);
27  dV=I2*(R_LV*cos(Th)+X_LV*sin(Th));
28  VR=(dV/V2)*100;     disp(VR,'voltage regulation(%)');
29  Pi=P0;
30  Pc=Psc;
31  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

```
1  // To calculate harmanic factor for stator
2
3  clc;
4  S=36;        //no of slots
5  q=3;         //no of phases
6  p=4;         //no of poles
7  m=S/(q*p);       //slots/pole/phase
8  g=180*p/S;       //gamma elec
9  function [k]=bfctr(n)
10     k=sind(m*n*g/2)/(m*sind(n*g/2));
11 endfunction
12
13 K_b=bfctr(1);
14 disp(K_b,'K_b(fundamental)');
15
16 K_b=bfctr(3);
17 disp(K_b,'K_b(third harmonic)');
18
19 K_b=bfctr(5);
```

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

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

```
1   // to find the frequency and phase and line voltages
2
3   clc;
4   n=375;          //speed in rpm
5   p=16;           //no of poles
6   f=n*p/120;
7   disp(f,'freq(Hz)');
8   S=144;          //no of slots
9   c=10;           //no of conductors/slot
10  t=S*c/2;        //no of turns
11  ph=3;
12  N_ph=t/ph;      //no of turns/ph
13  g=180*p/S;      //slots angle
14  m=S/(p*ph);     //slots/pole/phase
15  K_b=sind(m*g/2)/(m*sind(g/2));    //breadth factor
16  phi=0.04;       //flux per pole
17  E_p=4.44*K_b*f*N_ph*phi;
18  disp(E_p,'phase voltage(V)');
19  E_l=sqrt(3)*E_p;
20  disp(E_l,'line voltage(V)');
```

Scilab code Exa 5.3 to find the phase and line voltages

```
1   // to find the phase and line voltages
2
3   clc;
4   f=50;       //freq
5   n=600;      //speed in rpm
6   p=120*f/n;
```

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```
7  ph=3;
8  m=4;              //slots/pole/ph
9  S=p*ph*m;         //slots
10  t=12;            //turns per coil
11  N_ph=S*t/ph;
12  g=180*p/S;
13  K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
14  cp=10;            //coil pitch
15  pp=S/cp;          //pole pitch
16  theta_sp=(pp-cp)*g;     //short pitch angle
17  K_p=cosd(theta_sp/2);
18  phi=.035;
19  E_p=4.44*K_b*K_p*f*N_ph*phi;
20  disp(E_p,'phase voltage(V)');
21  E_l=sqrt(3)*E_p;
22  disp(E_l,'line voltage(V)');
```

Scilab code Exa 5.4 to calculate flux per pole

```
1  // to calculate flux/pole
2
3  clc;
4  S=42;
5  p=2;
6   f = 50;
7  ph=3;
8  m=S/(p*ph);      //slots/pole/phase
9  g=180*p/S;       //slots angle
10  K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
11  cp=17;
12  pp=S/p;
13  theta_sp=(pp-cp)*g;     //short pitch angle
14  K_p=cosd(theta_sp/2);
15  N_ph=S*2/(ph*p*2);          //2 parallel paths
16  E_p=2300/sqrt(3);
```

```
17  phi=E_p/(4.44*K_b*K_p*f*N_ph);
18  disp(phi,'flux/pole(Wb)');
```

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

```
1  // to calculate  useful flux/pole and ares of pole
       shoe
2
3  clc;
4  p=1500*1000;     //power
5  v=600;
6  I_a=p/v;
7  cu=25*1000;      //copper losses
8  R_a=cu/I_a^2;
9  E_a=v+I_a*R_a;
10 n=200;
11 Z=2500;
12 p=16;
13 A=16;
14 phi=E_a*60*A/(p*n*Z);
15 disp(phi,'flux/pole(Wb)');
16 fd=0.85;       //flux density
17 a=phi/fd;
18 disp(a,'area of pole shoe(m*m)');
```

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

```
1  // To calculate em power developed ,mech power fed ,
       torque provided by primemover
2
3  clc;
4  phi=32*10^-3;     //flux/pole
5  n=1600;           //speed in rpm
```

```
 6  Z=728;              //no of conductors
 7  p=4;
 8  A=4;
 9  E_a=phi*n*Z*(p/A)/60;
10  I_a=100;
11  P_e=E_a*I_a;
12  disp(P_e,'electromagnetic power(W)');
13  P_m=P_e;
14  disp(P_m,'mechanical power(W) fed');
15  w_m=2*%pi*n/60;
16  T=P_m/w_m;
17  disp(T,'primemover torque(Nm)');
```

Scilab code Exa 5.9 To determine peak value of fundamental mmf

```
 1  // To determine peak value of fundamental mmf
 2
 3  clc;
 4  f=50;
 5  n_s=300;
 6  p=120*f/n_s;
 7  P=400*1000;     //power
 8  V=3300;
 9  I_L=P/(sqrt(3)*V);
10  I_P=I_L;
11  I_m=sqrt(2)*I_P;     //max value of phase current
12  S=180;
13  g=180*p/S;
14  ph=3;
15  m=S/(p*ph);     //slots/pole/phase
16  K_b=sind(m*g/2)/(m*sind(g/2));     //breadth factor
17  c=8;          //conductors/1 coil side
18  N_ph=S*c/(ph*2);     //turns/phase
19  F_m=(4/%pi)*K_b*(N_ph/p)*I_m;
20  F_peak=(3/2)*F_m;
```

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

Scilab code Exa 5.10 to calculate field current and flux per pole and to calculate

```
1   // (a)to calculate field current and flux/pole(b)to
        calculate open ckt ph and line voltages
2   // (c)to caculate field current
3
4   clc;
5   B_peak=1.65;
6   g=.008;
7   u_o=4*%pi*10^-7;
8   P=4;
9   K_b=.957;
10  N_field=364/2;
11  I_f=B_peak*%pi*g*P/((4*u_o)*(K_b*N_field));
12  disp(I_f,'field current(A)');
13  l=1.02;       //rotor length
14  r=.41/2;      //rotor radius
15  phi=(4/P)*B_peak*l*r;
16  disp(phi,'flux/pole(Wb)');
17  N_ph=3*11*P/2;
18  ga=60/3;      //slot angle
19  m=3;
20  f=50;
21  K_b=sind(m*ga/2)/(m*sind(ga/2));      //breadth factor
22  E_ph=sqrt(2)*%pi*K_b*f*N_ph*phi;
23  disp(E_ph,'E_ph(V)');
24  E_line=sqrt(3)*E_ph;
25  disp(E_line,'E_line(V)');
26  I_fnew=.75*I_f;
27  disp(I_fnew,'I_f(new)(A)');
```

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

```scilab
1  // to find fundamental mmf wave,speed and its peak
      value
2
3  clc;
4  p=4;
5  f = 50;
6  S=60;
7  g=180*p/S;
8  ph=3;
9  m=S/(p*ph);        //slots/pole/phase
10 K_b=sind(m*g/2)/(m*sind(g/2));      //breadth factor
11 I_L=48;
12 I_P=I_L/sqrt(3);
13 I_Pmax=I_P*sqrt(2);
14 c=24;            //conductors
15 N_ph=S*c/(ph*2);        //turns/phase
16 F_m=(4/%pi)*K_b*(N_ph/p)*I_Pmax;
17 disp(F_m,'F_m(AT/pole)');
18 F_peak=(3/2)*F_m;
19 disp(F_peak,'F_peak(AT/pole)');
20 n=120*f/p;
21 disp(n,'speed(rpm)');
```

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

```scilab
1  // to calculate resultant air gap flux/pole
2
3  clc;
4  F1=400;
5  F2=850;
6  a=123.6;
7  Fr=sqrt(F1^2+F2^2+2*F1*F2*cosd(a));
8  P=1.408*10^-4;          //permeance/pole
```

```
 9  phi_r=P*Fr;
10  disp(phi_r,'air gap flux/pole(Wb)');
```

Scilab code Exa 5.13 To calculate resultant AT per pole and peak air gap flux dens

```
 1  //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
 2
 3  clc;
 4  ph=3;
 5  S=36;
 6  c=8*2;
 7  p=4;
 8  f=50;
 9  N_ph=S*c/(ph*2);          //turns/phase
10  ga=180*p/S;
11  m=S/(p*ph);      //slots/pole/phase
12  K_b=sind(m*ga/2)/(m*sind(ga/2));      //breadth factor
13  V_L=400;
14  V_ph=V_L/sqrt(3);
15  phi_r=V_ph/(4.44*K_b*f*N_ph);
16  disp(phi_r,'phi_r(Wb/pole)');
17  D=.16;
18  l=0.12;
19  PA=%pi*l*D/4;          //pole area
20  B_rav=phi_r/PA;
21  B_rpeak=(%pi/2)*B_rav;
22  g=2*10^-3;
23  u_o=4*%pi*10^-7;
24  F_r=g*B_rpeak/u_o;
25  disp(F_r,'F_r(AT/pole)');
26  T=60;          //torque(Nm)
27  d=26;
28  F2=T/((%pi/2)*(p/2)^2*phi_r*sind(d));
```

```
29  disp(F2,'F2(AT/pole)');
30  F1=sqrt(F2^2+F_r^2-2*F2*F_r*sind(d));
31  disp(F1,'F1(AT/pole)');
32  w=acosd((F1^2+F_r^2-F2^2)/(2*F1*F_r));
33  disp(w,'angle(deg)');
34  K_w=K_b;
35  I_a=F1/((3/2)*(4*sqrt(2)/%pi)*K_w*(N_ph/p));
36  disp(I_a,'I_a(A)');
```

Scilab code Exa 5.14 to determine in F2 peak rotor AT max torque ele ip at max tor

```
1  //to determine in F2,peak rotor AT, max torque, ele
      i/p at max torque(motoring mode),open ckt voltage
      (generating mode)
2
3  clc;
4  disp('motoring mode');
5  K_w=.976;
6  N_pole=746;
7  p=4;
8  I_f=20;
9  F2=(4/%pi)*K_w*(N_pole/p)*I_f;
10  S = 48;
11  g = 1.5 *10^-3;
12  disp(F2,'F2(AT)');
13  B_r=1.6;
14  D=.29;
15  l=.35;
16  T_max=(p/2)*(%pi*D*l/2)*F2*B_r;
17  disp(T_max,'T_max');
18  f=50;
19  w_m=4*%pi*f/p;
20  P_in=T_max*w_m;
21  disp(P_in,'P_in(W)');
22
```

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

Scilab code Exa 5.15 to find motor speed

```
1  // to find motor speed
2
3  clc;
4  n=1500;           //speed of sync generator
5  p=4;
6  f=n*p/120;
7
8  p_im=6;
9  n_s=120*f/p_im;
10 s=0.05;           //slip
11 n_im=(1-s)*n_s;
12 disp(n_im,'speed of induction motor(rpm)');
```

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

```
1  //to find voltage available b/w slip rings and its
       freq
2
3  clc;
```

```
 4  disp('(a)');
 5  f=50;
 6  p=6;
 7  n_s=120*f/p;
 8  n=-1000;
 9  s=(n_s-n)/n_s;
10  f_s=f*s;
11  disp(f_s,'slip  freq(Hz)');
12  v2=100;
13  V2=s*v2;
14  disp(V2,'slip  ring  voltage(V)');
15
16  disp('(b)');
17  n=1500;
18  s=(n_s-n)/n_s;
19  f_s=abs(f*s);
20  disp(f_s,'slip  freq(Hz)');
21  v2=100;
22  V2=s*v2;
23  disp(V2,'slip  ring  voltage(V)');
```

Scilab code Exa 5.18 to find no of poles slip and freq of rotor currents at full l

```
 1  //to  find  no  of  poles ,  slip  and  freq  of  rotor
        currents  at  full  load ,  motor  speed  at  twice  of
        full  load
 2
 3  clc;
 4  n_s=600;
 5  f=50;
 6  P=120*f/n_s;
 7  disp(P,'no  of  poles');
 8  n=576;
 9  s=(n_s-n)/n_s;
10  disp(s,'slip');
```

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```
11  f2=s*f;
12  n_r=s*n_s;
13  disp(n_r,'rotor speed wrt rotating field (rpm)');
14  ss=f2*s;
15  n=(1-ss)*n_s;
16  disp(n,'motor speed(rpm)');
17  nn=528;
18  s_old=s;
19  s_new=(n_s-nn)/n_s;
20  fac=s_new/s_old;
21  disp(fac,'factor is');
```

Scilab code Exa 5.19 to calculate amplitude of travelling wave mmf peak value of a

```
1  // to calculate amplitude of travelling wave mmf,
      peak value of air flux density, velocity of wave,
       current freq at some desired velocity
2
3  clc;
4  K_w=.925;
5  N_ph=48;
6  I=750/sqrt(2);
7  wndnglgth=2;
8  wavelgth=wndnglgth/0.5;
9  p=2*wavelgth;
10  F_peak=(3/2)*(4*sqrt(2)/%pi)*K_w*(N_ph/p)*I;
11  disp(F_peak,'F_peak(A/m)');
12  g=.01;
13  u_o=4*%pi*10^-7;
14  B_peak=u_o*F_peak/g;
15  disp(B_peak,'B_peak(T)');
16  f=25;
17  B=.5;
18  v=f*B;      disp(v,'velocity(m/s)');
19  vv=72*10^3/3600;          //given velocity
```

```
20  f = vv /0.5;
21  disp (f ,'freq(Hz)');
```

Chapter 7

DC Machines

Scilab code Exa 7.1 to calculate no of parrallel path

```
1 // to calculate no of parrallel path
2
3 clc;
4 S=12;              //no of commutator segments
5 P=4;
6 Y_cs=S/P;          //slots
7 Y_b=2*Y_cs+1;
8 y_f=Y_b-2;
9 disp(y_f,'no of parralel path');
```

Scilab code Exa 7.2 to find spacing bw brushes

```
1 // to find spacing b/w brushes
2
3 clc;
4 S=22;
5 P=4;
6 Y_cs=floor(S/P);
```

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

Scilab code Exa 7.3 to calculate relevant pitches for wave windings

```
 1  //to  calculate  relevant  pitches  for  wave  windings
 2
 3  clc;
 4  S=16;
 5  P=6;
 6  Y_cs=floor(S/P);
 7  U=2;
 8  Y_b=Y_cs*U+1;
 9  C=16;
10  y_c=U*(C-1)/P;
11  y_f=2*y_c-Y_b;
12  disp(y_f,'no  of  pitches');
```

Scilab code Exa 7.4 to find distance bw brushes

```
 1  //  to  find  distance  b/w  brushes
 2
 3  clc;
 4  S=28;
 5  P=4;
 6  U=8;
 7  c=U*S/2;
 8  y_c=2*(c-1)/P;
```

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

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

```
 1  // to find the torque and gross mech power developed
 2
 3  clc;
 4  D=.3;
 5  l=.2;
 6  p=4;
 7  fd=.4;              //flux density
 8  phi=%pi*(D/p)*l*fd;          //flux/pole
 9  n=1500;
10  Z=400;
11  A=4;
12  E_a=phi*n*Z*(p/A)/60;
13  I_a=25;
14  mp=E_a*I_a;
15  disp(mp,'gross mech power developed(W)');
16  T=mp/(2*%pi*n/60);
17  disp(T,'torque developed(Nm)');
```

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

```
 1  // to calculate ratio of generator speed to motor
       speed
 2
```

```
 3 clc;
 4 V=220;
 5 P=4000;
 6 I_a=P/V;
 7 r_a=.4;              //armature resistance
 8 E_ag=V+I_a*r_a;
 9 E_am=V-I_a*r_a;
10 a=1.1;              //phi_m/phi_g
11 n=(E_ag/E_am)*a;
12 disp(n,'n_g/n_m');
```

Scilab code Exa 7.7 to calculate speed of motor

```
 1 // to calculate speed of motor
 2
 3 clc;
 4 V=230;
 5 R_f=115;            //field resistance
 6 I_f=V/R_f;
 7 P_g=100000;           //electric power (m/c running as
        generator)
 8 I_L=P_g/V;
 9 I_a=I_f+I_L;
10 R_a=.08;            //armature resitance
11 E_ag=V+I_a*R_a;
12 n_g=750;           //speed
13
14 P_m=9000;            //m/c running as motor
15 I_l=P_m/V;
16 I_A=I_l-I_f;
17 E_am=V-I_A*R_a;
18 n_m=(E_am/E_ag)*n_g;
19 disp(n_m,'motor speed(rpm)');
```

Scilab code Exa 7.8 to calculate electomagnetic power and torque

```
1  //to calculate electomagnetic power and torque
2
3  clc;
4  E_a=250;
5  R_a=.05;
6  n=3000;
7  w_m=(n*2*%pi)/60;
8  disp('when terminal voltage is 255V');
9  V_t=255;
10 I_a=(V_t-E_a)/R_a;
11 P_in=E_a*I_a;
12 disp(P_in,'electromagnetic power(W)');
13 T=P_in/w_m;
14 disp(T,'torque(Nm)');
15
16 disp('when terminal voltage is 248V');
17 V_t=248;
18 I_a=(E_a-V_t)/R_a;
19 P_in=E_a*I_a;
20 disp(P_in,'electromagnetic power(W)');
21 T=P_in/w_m;
22 disp(T,'torque(Nm)');
```

Scilab code Exa 7.9 to calculate electomagnetic power

```
1  //to calculate electomagnetic power
2
3  clc;
4  n_f=3000;        //field speed
5  n_a=2950;        //armature speed
```

```
 6  E=250;
 7  E_a=E*(n_a/n_f);
 8  V_t=250;
 9  R_a=0.05;
10  I_a=(V_t-E_a)/R_a;
11  P_in=V_t*I_a;
12  disp(P_in,'power(W)');
13  P=E_a*I_a;
14  disp(P,'electromagnetic power(W)');
```

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

```
 1  // to calculate cross and demagnetising turns/pole
 2
 3  clc;
 4  P=250000;
 5  V=400;
 6  I_a=P/V;          //armature current
 7  n=6;          //no of parallel path
 8  I_c=I_a/n;     //conductor current
 9  Z=720;          //lap wound conductors
10  AT_a=(1/2)*Z*I_c/n;
11
12  B=2.5*n/2;          //brush leadof 2.5 angular degrees
      (mech) from geo neutral
13  AT_c=AT_a*(1-(2*B)/180);
14  disp(AT_c,'cross magnetising ampere turns(AT/pole)')
      ;
15  AT_d=AT_a*((2*B)/180);
16  disp(AT_d,'demagnetising ampere turns(AT/pole)');
```

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

```scilab
1 //to calculate no of conductors on each pole piece
2
3 clc;
4 Z=256;
5 A=6;
6 P=6;
7 r=.71;            //ratio of pole arc to pole pitch
8 N_cw=(Z/(2*A*P))*r;
9 N_cc=ceil(2*N_cw);
10 disp(N_cc,'compensating conductors/pole');
```

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

```scilab
1 //to calculate no of turns reqd on each interpole
2
3 clc;
4 P=25000;
5 V=440;
6 I_a=P/V;
7 Z=846;
8 A=2;
9 P=4;
10 B_i=.5;
11 u_o=4*%pi*10^-7;
12 l_gi=.003;
13 AT_i=((I_a*Z)/(2*A*P))+(B_i*l_gi)/u_o;
14 N_i=ceil(AT_i/I_a);
15 disp(N_i,'no of turns');
```

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

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

```
 2
 3  clc;
 4  ATppole =[1200  2400  3600  4800  6000];
 5  V_i =[76  135  180  215  240];
 6  plot(ATppole,V_i);
 7  xlabel('AT/pole');
 8  ylabel('E_a(V)');
 9
10  V=240;
11  vd=25;              //voltage  drop  ie  I_a*(R_a+R_se)
12  E_a=V-vd;
13  AT_netfl =4800;
14  AT_sefl =2400;
15  AT_sh=AT_sefl;
16
17  AT_senl =(3/25)*AT_sefl;
18  AT_sh=2400;              //no  change
19  AT_netnl=AT_senl+AT_sh;
20  disp(AT_netnl,'mmf/pole  on  no  load(AT)');
21  n=850;
22  E_a=148;              //from  the  magnetising  curve
23  E_anl=240-3;
24  nnl=n*E_anl/E_a;
25  disp(nnl,'speed  at  no  load(rpm)');
```

Scilab code Exa 7.14 to estimate at full load internal induced emf voltage drop ca

```
 1  // to  estimate  at  full  load  internal  induced  emf,
       voltage  drop  caused  y  armature  rxn,  and  field
       current  ~  armature  rxn  demagnitisation
 2
 3  clc;
 4  I_f =[0  0.2  0.4  0.6  0.8  1  1.2  1.4];
 5  Voc =[10  52  124  184  220  244  264  276];
 6  plot(I_f,Voc);
```

```
7  xlabel('I_f(A)');
8  ylabel('Voc');
9
10 I_afl=50;
11 R_a=.3;
12 vd=I_afl*R_a;
13 V=240;
14 E_a=V+vd;
15 disp(E_a,'internal induced emf(V)');
16 V_oc=276;           //from magnetising curve,I_f=1.4
17 V_d=V_oc-E_a;
18 disp(V_d,'armature rxn vol drop(V)');
19 I_f=0.36;
20 K_ar=I_f/I_afl;
21 disp(K_ar,'armature rxn demagnetisation');
```

Scilab code Exa 7.16 to calculate terminal voltage and rated output current and ca

```
1  //to calculate terminal voltage and rated output
     current and calculate no of series turns/pole
2
3  clc;
4  P=100000;
5  V=200;
6  I_L=P/V;
7  I_f=5;
8  I_a=I_L+I_f;
9  I_se=I_a;
10 N_se=5;
11 N_f=1200;
12 I_feq=I_f+(N_se/N_f)*I_se;
13 n=1000;
14 E_a=225;
15 nn=950;
16 E_aa=E_a*(nn/n);
```

```
17  R_a =0.03;
18  R_se =0.004;
19  V_t = E_aa - I_a *( R_a + R_se );
20  disp ( V_t ,' terminal voltage (V) ');
21  I_fd =0.001875* I_a ;
22  V_t =200;
23  E_a = V_t + I_a *( R_a + R_se );
24  E_aa = E_a *( n / nn );
25  I_fnet =7.5;
26  N_f =1000;
27  N_se = ceil (( I_fnet + I_fd - I_f )*( N_f / I_a ));
28  disp ( N_se ,'no of series turns / pole ');
```

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

```
1  // to determine demagnetising AT/ pole and no of
        series turns reqd
2
3  clc ;
4  V_oc =[220 230 240 250 260 270];
5  I_f =[1 1.15 1.35 1.5 1.69 2.02];
6  plot ( I_f , V_oc );
7  xlabel ('I_f(A) ');
8  ylabel ('V_oc(V) ');
9
10 V =240;
11 I_a =83.3;
12 R_a =.12;
13 E_a = V + I_a * R_a ;
14 n =1150;
15 nn =1190;
16 Ea = E_a *( nn / n );
17 I_f =2.1;
18 I_fnet =1.65;
19 I_fd = I_f - I_fnet ;
```

```
20  N_sf =550;              //shunt  field  turns/pole
21  AT_d = N_sf * I_fd;
22  disp(AT_d,'demagnetising  AT_d/pole');
23
24  //at  no  load(1190rpm)
25  V_t =230;
26  I_f =1.43;
27  AT_f = N_sf * I_f;
28  R_f = V_t / I_f;
29
30  //at  load(1150rpm)
31  I_L = I_a -(V/R_f);
32  V_a =(V+ I_a *.045)/(1+(.045/R_f));
33  E_a = V_a + I_a *.12;
34  //consult  mag  field
35  Ea = E_a *(nn/n);
36  Ifn =1.675;      //needed
37  ATn = N_sf * Ifn;
38  If = V_a / R_f;
39  ATf = N_sf * If;
40
41  ATse = ATn + AT_d - AT_f;
42  I_L = I_a - If;
43  Nse = floor(ATse/I_L);
44  disp(Nse,'no  of  series  turns/pole');
```

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

```
1  // to  compute  terminal  voltage  at  rated  voltage
       current
2
3  clc;
4  R_a =0.05;
5  R_se =.01;
6  N_f =1000;
```

```
7  N_se=3;
8  I_sf=5.6;              //shunt field current
9  I_L=200;
10 I_a=I_L+I_sf;
11 N=N_f*I_sf+I_a*N_se;          //excitation ampere
      turns
12 I_freq=N/N_f;
13
14 E_a=282;
15 n=1200;
16 nn=1150;
17 Ea=E_a*(nn/n);
18 V_t=Ea-I_a*(R_a+R_se);
19 disp(V_t,'terminal voltage(V)');
```

Scilab code Exa 7.23 to calculate no series turns

```
1  //to calculate no series turns
2
3  clc;
4  I_sf=5.6;
5  N_f=1000;
6  AT_f=I_sf*N_f;
7  I_a=205.6;
8  Z=400;
9  I_L=200;
10 AT_d=Z*(I_a/I_L);
11 V_t=250;
12 R_a=0.05;
13 R_se=.01;
14 E_a=V_t+I_a*(R_a+R_se);
15 n=1150;
16 nn=1200;
17 Ea=E_a*(nn/n);
18
```

```
19  I_fnet =6.2;
20  ATnet = I_fnet * N_f ;
21
22  ATse = ATnet + AT_d - AT_f ;
23  Nse = ceil ( ATse / I_a );
24  disp ( Nse , 'no of series turns/pole ');
```

Scilab code Exa 7.24 to find generator output

```
1  //to find generator output
2
3  clc ;
4  P =20000;
5  V =250;
6  I_a = P / V ;
7  R_a =.16;
8  vd = I_a * R_a ;
9  function [P_o]= output ( E_a )
10     V_t = E_a - vd ;
11     P_o = I_a * V_t ;
12     disp ( P_o , 'generator output (W) ');
13  endfunction
14  disp ( 'at I_f=1A ');
15  E_a =150;
16  P_o = output ( E_a );
17  disp ( 'at I_f=2A ');
18  E_a =257.5;
19  P_o = output ( E_a );
20  disp ( 'at I_f =2.5A ');
21  E_a =297.5;
22  P_o = output ( E_a );
23
24  disp ( 'at speed 1200rpm ');
25  function [Ea]= ratio ( E_a );
26     Ea =.8* E_a
```

```
27 endfunction
28 disp('at I_f=1A');
29 E_a=150;
30 Ea=ratio(E_a);
31 P_o=output(Ea);
32 disp('at I_f=2A');
33 E_a=257.5;
34 Ea=ratio(E_a);
35 P_o=output(Ea);
36 disp('at I_f=2.5A');
37 E_a=297.5;
38 Ea=ratio(E_a);
39 P_o=output(Ea);
```

Scilab code Exa 7.25 to find power to the load

```
1 //to find power to the load
2
3 clc;
4 R_L=3;
5 R_a=.16;
6 function [P_o]=output(E_a)
7     I_a=E_a/(R_a+R_L);
8     P_o=I_a^2*R_L;
9     disp(P_o,'power fed to the load(W)');
10 endfunction
11 disp('at I_f=1A');
12 E_a=150;
13 P_o=output(E_a);
14 disp('at I_f=2A');
15 E_a=257.5;
16 P_o=output(E_a);
17 disp('at I_f=2.5A');
18 E_a=297.5;
19 P_o=output(E_a);
```

Scilab code Exa 7.28 to compute the generator induced emf when fully loaded in lon

```scilab
1  //to compute the generator induced emf when fully
      loaded in long shunt compound and short shunt
      compound
2
3  clc;
4  P=75000;
5  V_t=250;
6  I_L=P/V_t;
7  R_a=.04;
8  R_se=.004;
9  R_f=100;
10 disp('case of long shunt');
11 I_f=V_t/R_f;
12 I_a=I_L+I_f;
13 V_b=2;
14 E_aLS=V_t+I_a*(R_a+R_se)+V_b;
15 disp(E_aLS,'generator induced emf(V)');
16
17 disp('case of short shunt');
18 V_b=V_t+I_L*R_se;
19 I_f=V_b/R_f;
20 I_a=I_L+I_f;
21 E_aSS=V_t+(I_a*R_a)+2;
22 disp(E_aSS,'generator induced emf(V)');
23
24 d=(E_aLS-E_aSS)*100/V_t;
25 disp(d,'percent diff');
```

Scilab code Exa 7.29 to find field current and field resistance at rated terminal

```
1  // to find field current and field resistance at
       rated terminal voltage, em power and         torque
2
3  clc;
4  V_o=250;            //no load voltage
5  I_f=1.5;
6  R_f=V_o/I_f;       disp(R_f,'field resistance(ohm)');
7  P=25000;
8  V_t=220;
9  I_L=P/V_t;
10 I_a=I_L;           disp(I_a,'field current(A)');
11 R_a=.1;
12 E_a=V_t+I_a*R_a;
13 I_f=1.1;
14 R_f=V_t/I_f;          disp(R_f,'field resistance(ohm)'
       );
15 I_a=I_L-I_f;
16 emp=E_a*I_a;
17 disp(emp,'em power(W)');
18 n=1600;
19 emt=emp/(n*2*%pi/60);
20 disp(emt,'torque(Nm)');
21 I_fa=1.25;            //actual I_f
22 I_c=I_fa-I_f;
23 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 r

```
1  //to determine the reduction of flux/pole due to
       armature rxn
2
3  clc;
4  V=250;
5  R_a=.7;
```

```
6 function [phi]=arxn(I_a,n)
7     phi=(V-I_a*R_a)/n;
8 endfunction
9
10 phinl=arxn(1.6,1250);
11 disp(phinl,'flux/pole no load');
12
13 phil=arxn(40,1150);
14 disp(phil,'flux/pole load');
15
16 d=(phinl-phil)*100/phinl;
17 disp(d,'reduction in phi due to armature rxn(%)');
```

Scilab code Exa 7.33 to determine internal em torque developed

```
1 //to determine internal em torque developed
2
3 clc;
4 V=250;
5 I_a=85;
6 R_a=.18;
7 E_a=V-I_a*R_a;
8 n=1100;
9 T=E_a*I_a/(n*2*%pi/60);
10 disp(T,'torque(Nm)');
11 T_1=.8*T;    disp(T_1,'new torque(Nm)');
12 //T=K_a'*K_f*I_f*I_a=K_a'*K_f*.8*I_f*I_a1     so
13 I_a1=I_a/.8;
14 E_a1=V-I_a1*R_a;
15 //E_a=K_a'*K_f*I_f*n
16 //E_a1=K_a'*K_f*.8*I_f*n1     so
17 n1=(E_a1/E_a)*n/.8
18 disp(n1,'speed is(rpm)');
```

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Scilab code Exa 7.34 to determine speed calculate internal torque developed on loa

```
1  //to determine speed, calculate internal torque
        developed on load and no load
2
3  clc;
4  V=220;
5  R_f=110;
6  I_f=V/R_f;
7  I_L=5;
8  I_a0=I_L-I_f;
9  R_a=.25;
10 E_a0=V-I_a0*R_a;
11 n=1200;
12 T_0=(E_a0*I_a0)/(2*%pi*n/60);
13 disp(T_0,'torque at no load(Nm)');
14
15 I_L=62;
16 I_a1=I_L-I_f;
17 E_a1=V-I_a1*R_a;
18 n1=(E_a1/E_a0)*n/.95;    disp(n1,'speed(rpm)');
19 T_1=(E_a1*I_a1)/(2*%pi*n1/60);
20 disp(T_1-T_0,'torque at on load(Nm)');
```

Scilab code Exa 7.36 to sketch speed the speed torque characteristicsof the series

```
1  //to sketch speed the speed-torque characteristicsof
        the series motor connectedto mains by
      calculating speed and torque values at diff
      values of armature current
2
3  clc;
```

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```
4  Ise=[75 100 200 300 400];
5  V=250;
6  Ra=.08;
7  function [Ea]=Eaa(Ise)
8  Ea=V-Ra*Ise;
9  endfunction
10
11 Eav=[121.5 155 250 283 292];
12 n=1200;
13 function[nn]=speed(Ea,Eav)
14 nn=n*Ea/Eav;
15     endfunction
16 function [T]=torque(nn,Ea,Ise)
17     T=(60*Ea*Ise/(2*%pi*nn));
18 endfunction
19
20 Ise=75;
21 Ea=Eaa(Ise);
22 Eav=121.5;
23 nn1=speed(Ea,Eav);
24 T1=torque(nn1,Ea,Ise);
25
26 Ise=100;
27 Ea=Eaa(Ise);
28 Eav=155;
29 nn2=speed(Ea,Eav);
30 T2=torque(nn2,Ea,Ise);
31
32 Ise=200;
33 Ea=Eaa(Ise);
34 Eav=250;
35 nn3=speed(Ea,Eav);
36 T3=torque(nn3,Ea,Ise);
37
38 Ise=300;
39 Ea=Eaa(Ise);
40 Eav=283;
41 nn4=speed(Ea,Eav);
```

```
42  T4=torque(nn4,Ea,Ise);
43
44  Ise=400;
45  Ea=Eaa(Ise);
46  Eav=292;
47  nn5=speed(Ea,Eav);
48  T5=torque(nn5,Ea,Ise);
49
50  nn=[nn1 nn2 nn3 nn4 nn5];disp(nn,'speed(rpm)');
51  T=[T1 T2 T3 T4 T5];disp(T,'torque(Nm)');
52
53  plot(T,nn);
54  xlabel('T(Nm)');
55  ylabel('n(rpm)');
```

Scilab code Exa 7.37 to determine the power delivered to the fan torque developed

```
1  //to determine the power delivered to the fan,torque
        developed by the motor and calculate external
      resistance to be added to armature ckt
2
3  clc;
4  V=220;
5  Ra=.6;
6  Rse=.4;
7  Ia=30;
8  Ea=V-(Ra+Rse)*Ia;
9  P=Ea*Ia;      disp(P,'Power(W)');
10  n=400;
11  w=2*%pi*n/60;
12  T=P/w;      disp(T,'torque(Nm)');
13
14  nn=200;
15  T1=T*(nn/n)^2;
16  Iaa=Ia*nn/n;
```

```
17  w1=2*%pi*nn/60;
18  P1=T1*w1;disp(P1,'power developed when n=200 rpm((W)
      )');
19  Ea1=P1/Iaa;
20  Rext=(V-Ea1)/Iaa-(Ra+Rse);disp(Rext,'external
      resistance(ohm)');
```

Scilab code Exa 7.38 to determine the starting torque developed

```
1  // to determine the starting torque developed
2  clc;
3  P=180000;
4  V=600;
5  Ia=P/V;
6  Ra=.105;
7  Ea=V-Ia*Ra;
8  n=600;
9  nn=500;
10  Eaa=Ea*nn/n;
11  Iaa=282;      //from magnetising curve
12  Iad=Ia-Iaa;
13  Ias=500;      //at start
14  k=Iad/Ia^2;
15  Iae=Ias-Iad*k;
16  Eas=590;      //from magnetising curve
17  Ts=Eas*Ias/(2*%pi*nn/60);disp(Ts,'T_start(Nm)');
```

Scilab code Exa 7.39 to determine speed and mech power

```
1  //to determine speed and mech power
2
3  clc;
4  k=.2*10^-3;
```

```
5  Ia=250;
6  Iad=k*Ia^2;
7  Ianet=Ia-Iad;
8  Ea=428;      //from magnetising curve
9  V=600;
10 Ra=.105;
11 Eaact=V-Ia*Ra;
12 n=500;
13 nn=n*Eaact/Ea;disp(nn,'speed(rpm)');
14 Pmech=Eaact*Ia;disp(Pmech,'mech power debeloped(W)')
      ;
15 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

```
1  //to calculate the mmf per pole on no load and speed
       developed
2
3  clc;
4  ATsefl=2400;
5  ATsenl=(3/25)*ATsefl;
6  ATsh=ATsefl;
7  ATnet=ATsenl+ATsh;disp(ATnet,'mmf/pole(AT)');
8  Ea=148;      //from magnetising curve
9  V=240;
10 vd=3;
11 Eanl=V-vd;
12 n=850;
13 nnl=n*Eanl/Ea;
14 disp(nnl,'speed(rpm)');
```

Scilab code Exa 7.41 to calculate demagnetisising ampeare turns em torque starting

```scilab
1  //to calculate demagnetisising ampeare turns, em
      torque,starting torque and no of turns of the
      series field
2
3  clc;
4  P=10000;
5  Vt=240;
6  Ia=P/Vt;
7  If=.6;
8  Ra=.18;
9  Ri=0.025;
10 Ea=Vt-Ia*(Ra+Ri);
11 n=1218;
12 Eaa=Ea*Vt/Ea;
13 Iff=.548;     //from n-If characteristics
14 Ifd=If-Iff;
15 N_s=2000;     //shunt field turns
16 ATd=N_s*Ifd;     disp(ATd,'demagnetising ampere turns
      ');
17 T=Ea*Ia/(2*%pi*n/60);disp(T,'torque(Nm)');
18 Rf=320;
19 If=Vt/Rf;
20 ATd=165;      //given
21 Ifd=ATd/N_s;
22 Ifnet=If-Ifd;
23 n=1150;       //from n-If characteristics
24 //Ea=Ka*phi*w;     Ka*phi=k
25 k=Vt/(2*%pi*n/60);
26 Iastart=75;
27 Tstart=Iastart*k;disp(Tstart,'starting torque(Nm)');
28 n_0=1250;
29 Ea=240;
30 If=.56;      //from n-If characteristics
31 n=1200;
32 Rse=.04;
33 R=Rse+Ra+Ri;
34 Eaa=Ea-Ia*R;
35 nn=n*Ea/Eaa;
```

```
36  Ifnet =.684;       // from n−If  characteristics
37  Ifd = Ifnet - If ;
38  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 e

```
 1  // to  determine  shunt  field  current  of  the  motor ,
        demagnetising  effect  of  armature  rxn ,  determine
         series  field  turns / pole , speed  of  motor .
 2
 3  clc ;
 4  Voc =[180  200  220  240  250];
 5  If =[1.18  1.4  1.8  2.4  2.84];
 6  plot ( If , Voc );
 7  xlabel ( 'If (A) ');
 8  ylabel ( 'Voc (V) ');
 9  n_0 =1350;      // at  no  load
10  Vt =230;
11  Ea = Vt ;      // no  voltage  drop
12  If =1.08;      // from  occ  characteristic
13  disp ( If , 'If (A) ');
14  n =1350;
15  Ia =56.5;
16  R =.15;
17  Ea = Vt - Ia * R ;
18  Ifnet =1.8;      // from  occ  characteristic
19  Ifact =2.08;
20  Ifd = Ifact - Ifnet ;
21  N_s =1200;      // shunt  field  turns
22  ATd = N_s * Ifd ;      disp ( ATd , 'ATd ');
23
24  Rf =.033;
25  Ea = Vt - Ia *( R + Rf );
26  n =1230;
```

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```
27  nn=1350;
28  Eaa=Ea*nn/n;
29  Ifnet=2.41;ATnet=Ifnet*N_s;
30  If=1.08;
31  ATsh=If*N_s;
32  ATse=ATnet-ATsh+ATd;
33  Nse=ATse/Ia;    disp(floor(Nse),'series field turns'
        );
34  Nse=25;
35  ATse=Nse*Ia;
36  ATnet=ATsh-ATd+ATse;
37  Ifnet=ATnet/N_s;
38  Rs=.025;
39  Eaa=226;      //from occ
40  Eact=Vt-Ia*(R+Rs);
41  n=nn*Eact/Eaa;    disp(n,'speed(rpm)');
```

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

```
 1  //to find the no of starter sections reqd ,and
       resistance of each section
 2
 3  clc;
 4  I1=55;
 5  I2=35;
 6  g=I1/I2;
 7  V1=220;
 8  R1=V1/I1;
 9  Ra=.4;
10  n=log((R1/Ra)-g)+1;
11  disp((n),'no of starter sections reqd');
12
13  function [R]=res (re)
14      R=(1/g)*re;
15  endfunction
```

```
16  R_1=R1-res(R1);disp(R_1,'R1(ohm)');
17  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

```
1  //to find the lower current limit , motor speed at
       each stud
2
3  clc;
4  Pop=25*1000;
5  Vt=230;
6  Ra=.12;
7  rf=120;
8  Nfl=2000;
9  Iafl=Pop/Vt;
10  Iamax=1.5*Iafl;
11  k=5;
12  I1=Iamax;
13  R1=Vt/I1;
14  r=(R1/Ra)^(1/(k-1));
15  I2=I1/r;
16  function [R]=res (re)
17      R=(1/r)*re;
18  endfunction
19  R_1=R1-res(R1);disp(R_1,'R1(ohm)');
20  R_2=res(R_1);disp(R_2,'R2(ohm)');
21  R_3=res(R_2);disp(R_3,'R3(ohm)');
22  R_4=res(R_3);disp(R_4,'R4(ohm)');
23
24  Iaf1=103.7;
25  Ea=Vt-Iaf1*Ra;
26  Ka=Ea/Nfl;
27  function [n]=speed(r)
28      Ea=Vt-I2*r;
29      n=Ea/Ka;
```

```
30  endfunction
31  r1=R1;
32  n1=speed(r1);disp(n1,'n1(rpm)');
33  r2=r1-R_1;
34  n2=speed(r2);disp(n2,'n2(rpm)');
35  r3=r2-R_2;
36  n3=speed(r3);disp(n3,'n3(rpm)');
37  r4=r3-R_3;
38  n4=speed(r4);disp(n4,'n4(rpm)');
```

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

```
1  //to calculate the ratio of full load speed to no
       load speed
2
3  clc;
4  V=400;
5  Rf=200;
6  If=V/Rf;
7  Inl=5.6;
8  I_a0=Inl-If;
9  vd=2;       //voltage drop
10  Ra=.18;
11  E_a0=V-Ra*I_a0-vd;
12  Ifl=68.3;
13  Iafl=Ifl-If;
14  E_afl=V-Ra*Iafl-vd;
15  e=.03;      //armature rxn weakens the field by 3%
16  k=(E_afl/E_a0)*(1/(1-e));
17  disp(k,'n_fl/n_nl');
```

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

```
1  //to calculate load torque, motor speed and line
      current
2
3  clc;
4  V=250;
5  Rf=41.67;
6  If1=V/Rf;
7  Ia=126;
8  Ia1=Ia-If1;
9  Ra=.03;
10 Ea1=V-Ra*Ia1;
11 n1=1105;        //rpm
12 w1=2*%pi*n1/60;
13 Ka=Ea1/(If1*w1);
14 T=Ka*If1*Ia1;
15 disp(T,'torque(Nm)');
16
17 If2=5;
18 Ia2=Ia1*(If1/If2);
19 I_L2=Ia2+2;disp(I_L2,'motor current(A) initial');
20 Ea2=V-Ra*Ia2;
21 w2=Ea2/(Ka*If2);
22
23 If1=6;
24 Voc1=267;
25 n=1200;
26 k1=Voc1/(2*%pi*n/60);       //k=Ka*phi
27 If1=5;
28 Voc2=250;
29 n=1200;
30 k2=Voc2/(2*%pi*n/60);       //k=Ka*phi
31 Ia2=Ia1*(k1/k2);
32 I_L2=Ia2+2;disp(I_L2,'motor current(A) final');
33 Ea2=V-Ra*Ia2;
34 w2=Ea2/k2;
35 disp(w2,'motor speed(rad/s)');
```

Scilab code Exa 7.47 to calculate armature current speed and value of external res

```
1  //to calculate armature current ,speed and value of
       external resistance in field ckt
2
3  clc;
4  V=250;
5  Ia=5;
6  Ra=.6;
7  n=1000;
8  k=(V-Ia*Ra)/(2*%pi*n/60);
9  T=100;
10 Ia=T/k;disp(Ia,'armature current(A)');
11 w_m=(V-Ia*Ra)/k;
12 n=(60*w_m)/(2*%pi);disp(n,'speed(rpm)');
13
14 Rf=150;
15 If=V/Rf;
16 kk=k/If;
17 Iaa=44.8;
18 nn=1200;
19 Iff=(V-Iaa*Ra)/(kk*2*%pi*nn/60);
20 Rftot=V/Iff;
21 Rfext=Rftot-Rf;
22 disp(Rfext,'external resistance(ohm)');
```

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

```
1  //to determine speed and torque of the motor
2
3  clc;
4  Ra=0.035;
```

```scilab
 5  Rf =0.015;
 6  V=220;
 7  I=200;
 8  Ea=V-I*(Ra+Rf);
 9  disp('full field winding');
10  n=900;
11  nn=n*Ea/V;disp(nn,'speed(rpm)');
12  T=(Ea*I/2)/(2*%pi*nn/60);disp(T,'torque(Nm)');
13  disp('field winding reduced to half');
14  Rse=Rf/2;
15  Rtot=Rse+Ra;
16  Ea=V-I*(Rtot);
17  Iff=I/2;
18  V=150;     //from magnetisation characteristic
19  nn=n*Ea/V;disp(nn,'speed(rpm)');
20  T=(Ea*I)/(2*%pi*nn/60);disp(T,'torque(Nm)');
21
22  disp('divertor across series field');
23  Ra=0.03;
24  Rse=.015;
25  Kd=1/((Rse/Ra)+1);
26  Ise=Kd*I;
27  V1=192;
28  I1=150;
29  V2=150;
30  I2=100;
31  v=V2+((V1-V2)/(I1-I2))*(Ise-I2);
32  R=(2/3)*Rse;
33  Ea=V-I*(Ra+R);
34  nn=n*Ea/v;disp(nn,'speed(rpm)');
35  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

```scilab
 1  //to determine speed regulation, load speed and
```

```scilab
     power regulation and compare power wasted in both
        cases
 2
 3  clc;
 4  V=230;
 5  Ra=2;
 6  Ia=5;
 7  Ea=V-Ia*Ra;
 8  n=1250;
 9  w=2*%pi*n/60;
10  k=Ea/w;      //k=Ka*phi
11  Re=15;
12  Ia0=1;
13  Ea=V-Ia0*(Ra+Re);
14  w0=Ea/k;
15  Ia=5;
16  Ea=V-Ia*(Ra+Re);
17  w=Ea/k;
18  wr=(w0-w)*100/w;
19  disp(wr,'(i)speed regulation(%)');
20
21  R1=10;
22  R2=15;
23  B=R2/(R1+R2);
24  V_TH=V*B;
25  R_TH=R1*B;
26  Ea=V_TH-Ia0*(R_TH+Ra);
27  w0=Ea/k;
28  Ia=5;
29  Ea=V_TH-Ia*(R_TH+Ra);
30  w=Ea/k;
31  wr=(w0-w)*100/w;
32  disp(wr,'(ii)speed regulation(%)');
33
34  Pe=Ia^2*Re;
35  disp(Pe,'power loss by rheostat control(W)');
36  Ra=2;
37  Ea=98;
```

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```
38  Va=Ea+Ra*Ia;
39  P2=Va^2/R2;
40  I2=Va/R2;
41  I1=I2+Ia;
42  P1=I1^2*R1;
43  Pe=P1+P2;
44  disp(Pe,'power loss by shunted armature control(W)')
        ;
```

Scilab code Exa 7.52 to determine armature current

```
1  //to determine armature current
2
3  clc;
4  n1=1600;
5  Ia1=120;
6  n2=400;
7  Ia2=(n1*Ia1)/n2;      //P=K*Ia*n
8  disp(Ia2,'Ia(A)');
```

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

```
1  //to find speed and ratio of mech o/p
2
3  clc;
4  V=400;
5  Ra=.25;
6  Ia1=25;
7  Ea1=V-Ra*Ia1;
8  n1=1200;
9  Rr=2.75;
10 Ia2=15;
11 Ea2=V-(Ra+Rr)*Ia2;
```

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```
12  phi =.7;        // phi=(phi(15)/phi(25))
13  n2=(Ea2/Ea1)*n1/phi;
14  disp(n2,'speed(rpm)');
15
16  Po2=Ea2*Ia2;
17  Po1=Ea1*Ia1;
18  disp(Po2/Po1,'ratio of mech o/p');
19  Ia=120;      //Ia is constant indep of speed
20  disp(Ia,'Ia(A)');
```

Scilab code Exa 7.55 to calculate the armature voltage reqd

```
1  //to calculate the armature voltage reqd
2
3  clc;
4  V=500;
5  Ra=.28;
6  Ia1=128;
7  Ea1=V-Ia1*Ra;
8  //(Vt2-.28*Ia2)-->n1/sqrt(2)      (i)
9  //Ea1-->n1      (ii)
10  Vt2=(Ea1/sqrt(2))+(Ia1*Ra);
11  disp(Vt2,'armature voltage(V)');
```

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

```
1  //to find the range of generator field current ,motor
        current and speed
2
3  clc;
4  If=[0 0.2 0.3 0.4 0.5 0.6 0.7 0.8 1 1.2];
5  Voc=[45 110 148 175 195 212 223 230 241 251];
6  plot(If,Voc);
```

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```
 7  xlabel('If(A)');
 8  ylabel('Voc(V)');
 9  Ifm=0.8;
10  Eam2=230;        //at 1500rpm
11  n_m2=1500;
12  Ra=.5;
13  //n_m=300-1500rpm(range)
14  n_m1=300;
15  Eam1=Eam2*n_m1/n_m2;
16  P_mot=4500;
17  Ia1=P_mot/Eam1;
18  Eag1=Eam1+2*Ra*Ia1;
19  If1=.3-((.1/(148-110))*(148-Eag1));
20  disp(If1,'lower limit of current(A)');
21
22  n_m2=1500;
23  Eam2=230;
24  P_mot=4500;
25  Ia2=P_mot/Eam2;
26  Eag2=Eam2+2*Ra*Ia2;
27  If2=1.2-(.2/(241-230)*(251-Eag2));
28  disp(If2,'upper limit of current(A)');
29
30  Ifg=1;
31  Eag=241;
32  n=1500;
33  Pop=4500;
34  //((241-Eam)/(2*.5))*Eam=4500
35  //after solving
36  //Eam^2-241*Eam+4500=0
37  function [x]=quad(a,b,c)
38      d=sqrt(b^2-4*a*c);
39      x1=(-b+d)/(2*a);
40      x2=(-b-d)/(2*a);
41      if(x1<x2)
42          x=x2;
43      else
44          x=x1;
```

```
45      end
46  endfunction
47  Eam=quad(1,-241,4500);
48  Ifm=.2;
49  Eamm=110;
50  n_m=n*Eam/Eamm;disp(n_m,'speed(rpm)');
51  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 generatin

```
1  //to calculate m/c eff as a generator and max eff
       when generating and motoring.
2
3  clc;
4  Pop=10*1000;
5  Vt=250;
6  Ra=.8;
7  Rf=275;
8  Ia=3.91;
9  Psh=Vt^2/Rf;
10  Prot=Vt*Ia-Ia^2*Ra;disp(Prot,'rotational loss(W)');
11
12  I1=Pop/Vt;
13  If=Vt/Rf;
14  Ia=I1+If;
15  Ploss=Prot+Psh+Ia^2*Ra;
16  Eff_gen=(1-Ploss/(Ploss+Pop))*100;disp(Eff_gen,'
       generator eff(%)');
17
18  Ia=I1-If;
19  Ploss=Prot+Psh+Ia^2*Ra;
20  Eff_motor=(1-Ploss/(Pop))*100;disp(Eff_motor,'motor
       eff(%)');
21
22  Ia=sqrt((Prot+Psh)/Ra);
```

```
23  Ploss_tot =2*( Prot+Psh ); disp ( Ploss_tot , ' t o t a l   l o s s (W)
        ' ) ;
24
25  I1=Ia -If ;
26  Pout=Vt*I1 ;
27  Eff_gen_max =((1 - Ploss_tot /( Ploss_tot+Pout )))*100;
28  disp ( Eff_gen_max , 'max  g e n e r a t o r   e f f (%) ' ) ;
29
30  I1=Ia+If ;
31  Pin=Vt*I1 ;
32  Eff_motor_max =((1 - Ploss_tot /( Pin )))*100; disp (
        Eff_motor_max , 'max  motor   e f f (%) ' ) ;
```

Scilab code Exa 7.59 to determine rotational loss no load armature current and spe

```
 1  // to  determine  r o t a t i o n a l  l o s s ,  no  load  armature
        current  and  speed  and  a l s o  find  speed  r e g u l a t i o n
        and  to  c a l c u l a t e  armature  current  for  given  em
        torque
 2
 3  clc ;
 4  Pout =60*1000;
 5  eff =.85;
 6  P_L =((1/ eff ) -1)*Pout ;
 7  Pin=Pout +P_L ;
 8  V=600;
 9  I_L=Pin/V ;
10  Rf =100;
11  If=V/Rf ;
12  Ia=I_L -If ;
13  Ra =.16;
14  Ea=V-Ia*Ra ;
15  n=900;
16  Prot=P_L -Ia^2*Ra -V*If ; disp ( Prot , ' r o t a t i o n a l   l o s s (W) '
        ) ;
```

```
17
18  Iao=Prot/V;disp(Iao,'no load armature current(A)');
19  Eao=V;
20  n0=n*Eao/Ea;disp(n0,'no load speed(rpm)');
21  reg=(n0-n)*100/n;disp(reg,'speed regulation(%)');
22
23  K=Ea/(2*%pi*n/60);      //K=Ka*phi
24  T=600;
25  Ia=T/K;disp(Ia,'reqd armature current(A)');
```

Scilab code Exa 7.60 to determine load torque and motor eff armature current for m

```
1  //to determine load torque and motor eff ,armature
      current for max motor eff and ots value
2
3  clc;
4  V=250;
5  Ia=35;
6  Ra=.5;
7  Ea=V-Ia*Ra;
8  Poutg=Ea*Ia;
9  Prot=500;
10  Pout_net=Poutg-Prot;
11  n=1250;
12  w=2*%pi*n/60;
13  T_L=Pout_net/w;disp(T_L,'load torque(Nm)');
14
15  Rf=250;
16  If=V/Rf;
17  I_L=If+Ia;
18  Pin=I_L*V;
19  eff=Pout_net*100/Pin;disp(eff,'efficiency(%)');
20
21  Pk=Prot+V*If;
22  Ia=sqrt(Pk/Ra);disp(Ia,'armature current(A)');
```

```
23  Tloss=2*Pk;
24  I_L=If+Ia;
25  Pin=I_L*V;
26  eff_max=1-(Tloss/Pin);disp(eff_max*100,'max
        efficiency(%)');
27
28  Ea1=V-Ia*Ra;
29  n1=n*Ea1/Ea;disp(n1,'speed(rpm)');
30  w=2*%pi*n1/60;
31  Poutg=Ea1*Ia;
32  Pout_net=Poutg-Prot;
33  T_L=Pout_net/w;disp(T_L,'load torque(Nm)');
```

Scilab code Exa 7.61 to calculate rotational loss armature resistance eff line cur

```
1  //to calculate rotational loss ,armature resistance,
       eff,line current and speed
2
3  clc;
4  Pshaft=20000;
5  eff=.89;
6  P_L=((1/eff)-1)*Pshaft;
7  Pin=Pshaft+P_L;
8  V=250;
9  I_L=Pin/V;disp(I_L,'line current(A)');
10 Rf=125;
11 If=V/Rf;
12 Ia=I_L-If;
13
14 Ploss=P_L/2;
15 Ra=Ploss/Ia^2;disp(Ra,'armature resistance(ohm)');
16 Psh=V*If;
17 Prot=Ploss-Psh;disp(Prot,'rotational loss(W)');
18 Ea=V-I_L*Ra;
19 n=850;
```

```
20  Ia=100;
21
22  Pc=Ia^2*Ra;
23  P_L=Pc+Ploss;
24  Pin=V*I_L;
25  eff=(1-P_L/Pin)*100;
26  Ea1=V-Ia*Ra;
27  n1=n*Ea1/Ea;disp(n1,'speed(rpm)');
```

Scilab code Exa 7.62 to calculate eff of motor and generator

```
1  //to calculate eff of motor and generator
2
3  clc;
4  Iag=60;
5  Ia=15;
6  Iam=Iag+Ia;
7  Vt=250;
8  Ram=.2;
9  Rag=.2;
10  Pstray=.5*(Vt*Ia-Iam^2*Ram-Iag^2*Rag);
11  Ifm=2;
12  Pinm=Vt*(Iam+Ifm);
13  P_Lm=(Pstray+Vt*Ifm)+Iam^2*Ram;
14  eff_M=1-(P_Lm/Pinm);disp(eff_M*100,'efficiency of
       motor(%)');
15
16  Iag=60;
17  Ifg=2.5;
18  P_Lg=(Pstray+Vt*Ifg)+Iag^2*Rag;
19  Poutg=Vt*Iag;
20  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 t

```
1  //to calculaate torque constt,value of rotational
       loss,stalled torque and stalled current of motor,
       armature current anad eff, motor o/p and eff
2
3  clc;
4  Vt=6;
5  Iao=.0145;
6  n=12125;
7  w=2*%pi*n/60;
8  Ra=4.2;
9  Ea=Vt-Iao*Ra;
10 Km=Ea/w;disp(Km,'torque constt');
11
12 Prot=Ea*Iao;disp(Prot,'rotational loss(W)');
13
14 Ia_stall=Vt/Ra;disp(Ia_stall,'stalled current(A)');
15 Tstall=Km*Ia_stall;disp(Tstall,'stalled torque(Nm)')
       ;
16
17 Poutg=1.6;
18 function [x]=quad(a,b,c)
19     d=sqrt(b^2-4*a*c);
20     x1=(-b+d)/(2*a);
21     x2=(-b-d)/(2*a);
22     if(x1>x2)
23          x=x2;
24     else
25          x=x1;
26     end
27 endfunction
28 //Ea*Ia=1.6;
29 //(Vt-Ra*Ia)*Ia=Poutg;
```

```
30  Ia=quad(Ra,-Vt,Poutg);
31  Ea=Vt-Ia*Ra;
32  wo=Ea/Km;
33  Proto=Prot*(w/wo)^2;
34  Pout_net=Poutg-Prot;
35  Pi=Vt*Ia;
36  eff=Pout_net/Pi;disp(eff*100,'efficiency(%)');
37
38  n1=10250;
39  w1=2*%pi*n1/60;
40  Km=.004513;
41  Ea1=Km*w1;
42  Ia=(Vt-Ea1)/Ra;
43  Pout_gross=Ea1*Ia;
44  Prot1=Prot*(n1/n);
45  Pout_net=Pout_gross-Prot1;disp(Pout_net,'o/p power(W
       )');
46  Pin=Vt*Ia;
47  eff=Pout_net/Pin;disp(eff*100,'efficiency(%)');
```

Chapter 8

Synchronous Machines

Scilab code Exa 8.2 to determine voltage regulation by mmf method

```
1 //to determine voltage regulation by mmf method
2
3 clc;
4 pf=0.85;
5 P=150*10^6;
6 V=13*1000;
7 Iarated=P/(sqrt(3)*pf*V);
8 If=750;
9 Ifocc=810;
10 B=acosd(pf);
11 Ff=sqrt((Ifocc+If*sind(B))^2+(If*cosd(B))^2);
12 Ef=16.3*1000;
13 vr=Ef/V-1;
14 disp(vr*100,'voltage regulation(%)');
```

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

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

```
2
3  clc;
4  If=[50 75 100 125 150 162.5 200 250 300];
5  Voc=[6.2 8.7 10.5 11.6 12.8 13.7 14.2 15.2 15.9];
6  plot(If,Voc);
7  xlabel('If(A)');
8  ylabel('Voc(V)');
9
10 r=10*10^6;      //rating
11 V=13000;
12 Ia=r/(sqrt(3)*V);
13 I_SC=688;       //corresponding to V
14 Xs=V/(sqrt(3)*I_SC);disp(Xs,'sync reactance(ohm)');
15 V_a=1200;
16 Xl=V_a/(sqrt(3)*Ia);disp(Xl,'leakage reactance(ohm)'
      );
17 Ifar=90;
18 Er=complex(V,sqrt(3)*Ia*Xl);
19 If=185;      //corresponding to Er
20 Iff=sqrt((If+Ifar*sind(40.5))^2+(Ifar*cosd(40.5))^2)
      ;
21 Eff=15200;      //corresponding to Iff
22 vr=(Eff/V-1)*100;disp(vr,'voltage regulation(%)');
23
24 Xsadj=Xs*complex(.8,-.6);j=sqrt(-1);
25 Ef=(V+sqrt(3)*Ia*Xsadj);
26 If=(150/13)*abs(Ef);
27 Vtoc=14800;      //corresponding to If
28 vr=(Vtoc/V-1)*100;disp(vr,'voltage regulation(%)');
```

Scilab code Exa 8.6 to calculate the excitation emf

```
1  //to calculate the excitation emf
2
3  clc;
```

```
4  Vt =3300;
5  Xs =18/3;
6  pf =.707;
7  P=800*1000;
8  Ia=P/(sqrt(3)*Vt*pf);
9  a=Ia*Xs/sqrt(2);
10 b=Vt/sqrt(3);
11 Ef=sqrt((a+b)^2+a^2)*sqrt(3);
12 disp(Ef,'excitation emf(V)(line)');
```

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

```
1  //to compute the max power and torque,terminal
      voltage
2
3  clc;
4  V=3300;
5  Vt=V/sqrt(3);
6  P=1000*10^3;
7  pf=1;
8  Ia=P/(V*sqrt(3)*pf);
9  Xsm=3.24;
10 j=sqrt(-1);
11 Efm=Vt-j*Ia*Xsm;
12 Efg=abs(Efm);
13 P_emax=3*Vt*Efg/Xsm;disp(P_emax,'max power(W)');
14 p=24;
15 f=50;
16 w_sm=(120*f*2*%pi)/(p*60);
17 Tmax=P_emax/w_sm;disp(Tmax,'torque(Nm)');
18
19 Xsg=4.55;
20 Efm=Vt-j*Ia*Xsg;
21 Efmm=abs(Efm);
22 X=Xsm+Xsg;
```

```
23  P_emax =3* Efg * Efmm /X; disp ( P_emax , 'max power (W) ') ;
24  Tmax = P_emax / w_sm ; disp ( Tmax , 'torque (Nm) ') ;
25
26  d =90;
27  Efm = Efg * complex ( cosd (0) , sind (0) ) ;
28  Efg = Efmm * complex ( cosd (d) , sind (d) ) ;
29  Ia =( Efg - Efm ) /( j*X) ;
30  v=j* Ia * Xsm ;
31  Vt = Efm +j* Ia * Xsm ;
32  disp ( abs ( Vt ) * sqrt (3) , 'line voltage (V) ') ;
```

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

```
1  // max power supplied , power angle d, corresponding
       field current
2
3  clc ;
4  j= sqrt ( -1) ;
5  r =100*10^6;      // va
6  V =11000;
7  P =100*10^6;
8  Ef =1;      // pu
9  Vth =1;       // pu
10  Xs =1.3;       // pu
11  Xth =.24;       // pu
12  P_emax = Ef * Vth /( Xs + Xth ) ; disp ( P_emax , 'max power
       delivered ( pu ) ') ;
13
14  Pe =1;
15  Vt =1;
16  d= asind ( Pe * Xth /( Vt * Vth ) ) ; disp (d , 'power angle ') ;
17  Vt = exp (j*d) ;
18  Ia =( Vt - Vth ) /( j* Xth ) ;
19  Ef = Vth +j*( Xs + Xth ) * Ia ;
20  Voc =11000;
```

```
21  If =256;
22  Ff =19150;
23  Iff = If * Ff / Voc ;
24  disp ( Iff , 'If (A) ');
25
26  Pe =0:0.01:0.8;
27  Vt =1+(0.24/1.54) *(1.54* Pe -1) ;
28  plot ( Pe , Vt );
29  xlabel ('load ');
30  ylabel ('Vt (V) ');
31
32  Pe =0:0.01:0.8;
33  dl = asind (0.24* Pe );
34  Ef =1+(1.54/.24) *( exp (j* dl ) -1) ;
35  If =(256/11) * Ef ;
36  plot ( Pe , abs ( If ));
37  xlabel ('load ');
38  ylabel ('excittion  current ');
```

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

```
1  //to  calculate  the  generator  current  and  its  pf
2
3  clc ;
4  j= sqrt ( -1);
5  X =.24;
6  r =400;      //rating  in  MVA
7  rr =600;      //rating  in  MVA
8  Pe =r/ rr ;
9  Vt =1;
10  Vth =1;
11  dl = asind ( Pe *X/( Vt * Vth ));
12  Ia =2* sind ( dl /2)/X;
13  V =24000;
14  IaB =( rr /3) *10^6/( V/ sqrt (3) );
```

```
15  Iaa=Ia*IaB;disp(Iaa,'generating current(A)');
16  phi=dl/2;
17  pf= cosd(phi);disp(pf,'power factor');
18
19  Pe=1;
20  dl1=asind(Pe*X/(Vt*Vth));
21  Ia=2*sind(dl1/2)/X;
22  Iaa=Ia*IaB;disp(Iaa,'generating current(A)');
23  phi=dl1/2;
24  pf= cosd(phi);disp(pf,'power factor');
25  Ef=Vt+j*Ia*(complex(cosd(-phi),sind(-phi)))*X;
26  Eff=abs(Ef)*V;
27  dl2=atand(imag(Ef)/real(Ef));
28
29  Xth=.24;
30  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 str

```
1  //to calculate armature resistance, sync reactance,
        full load stray load loss, Rac/Rdc, various
        categories of losses at full load, full load eff
2
3  clc;
4  r=60*10^3;
5  Psc=3950;
6  Isc=108;
7  Raeff=Psc/(3*Isc^2);disp(Raeff,'effective armature
        resistance(ohm)');
8  V=400;
9  Ifoc=2.85;
10  Ifsc=1.21;
11  I_SC=Isc*Ifoc/Ifsc;
12  Zs=(V/sqrt(3))/I_SC;
```

```
13  Xs=sqrt(Zs^2-Raeff^2);disp(Xs,'sync reactance(ohm)')
       ;
14
15  t1=25;
16  t2=75;
17  Rdc=0.075;
18  Radc=Rdc*((273+t2)/(273+t1));
19  Iarated=r/(sqrt(3)*V);
20  Pscc=Psc*(Iarated/Isc)^2;
21  P=3*Iarated^2*Radc;disp(P,'armature loss(W)');
22  loss=Pscc-P;disp(loss,'loss(W)');
23
24  a=Raeff/Radc;disp(a,'Rac/Rdc');
25
26  Pwf=900;disp(Pwf,'windage and friction loss(W)');
27  tloss=2440;
28  closs=tloss-Pwf;disp(closs,'core loss(W)');
29  If=3.1;
30  Rf=110;
31  Pcu=If^2*Rf;disp(Pcu,'field cu loss(W)');
32  disp(loss,'stray load loss(W)');
33  b=loss+Pcu+closs+Pwf+P;
34  disp(b,'total loss(W)');
35
36  pf=0.8;
37  op=r*pf;
38  ip=op+b;
39  eff=op/ip;
40  disp(eff,'efficiency');
```

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

```
1  //to calculate net power op,eff,line current and pf
2
3  clc;
```

```
 4 j=sqrt(-1);
 5 Zs=(1/3)*(.3+j*6);
 6 phi=atand(imag(Zs)/real(Zs));
 7 Vt=400/sqrt(3);
 8 Ef=600/sqrt(3);
 9 a=sqrt(Vt^2+Ef^2-2*Vt*Ef*cosd(phi));
10 Ia=a/abs(Zs);disp(Ia,'line current(A)');
11 B=acosd((Vt^2+a^2-Ef^2)/(2*Vt*a));
12
13 phi=90-(90-atand(imag(Zs)/real(Zs)))-B;disp(cosd(phi
    ),'pf');
14 Pein=Vt*Ia*cosd(phi);
15 Ra=.1;
16 b=Ia^2*Ra;
17 loss=2400;
18 Pmout=Pein-loss/3-b;disp(Pmout,'net power op(W)');
19 eff=Pmout/Pein;
20 disp(eff*100,'efficiency(%)');
```

Scilab code Exa 8.12 to find pf

```
 1 //to find pf
 2
 3 clc;
 4 j=sqrt(-1);
 5 Zs=.8+j*5;
 6 Vt=3300/sqrt(3);
 7 Pein=800*10^3/3;     //per ph
 8 pf=.8;
 9 Qe=-Pein*tand(acosd(pf));
10 //a=Ef*sind(dl-a);
11 //b=Ef=cosd(dl-a);
12 a=((abs(Zs)/Vt)*(Pein-real(Zs)*(Vt/abs(Zs))^2));
13 b=((abs(Zs)/Vt)*(-Qe+imag(Zs)*(Vt/abs(Zs))^2));
14
```

```
15  Ef = sqrt(a^2+b^2);
16
17  Pein = (1200/3)*1000;
18  a = asind((abs(Zs)/(Vt*Ef))*(Pein-pf*(Vt/abs(Zs))^2));
19  Qe = imag(Zs)*(Vt/abs(Zs))^2-Ef*Vt*cosd(a)/abs(Zs);
20  pf = cosd(atand(Qe/Pein));
21  disp(pf,'pf');
```

Scilab code Exa 8.13 to determine excitation emf torque angle stator current pf ma

```
1  //to determine excitation emf, torque angle,stator
       current, pf, max power, kVAR delivered
2
3  clc;
4  j = sqrt(-1);
5  P = 10000;
6  V = 400;
7  Ia = P/(sqrt(3)*V);
8  pf = .8;
9  phi = acosd(pf);
10  Iaa = Ia*complex(cosd(-phi),sind(-phi));
11  Vt = V/sqrt(3);
12  X = 16;
13  Ef = Vt+j*X*Iaa;
14  disp(abs(Ef),'excitation emf(V)');
15  dl = atand(imag(Ef)/real(Ef));
16  disp(dl,'torque angle');
17
18  Pe = P*pf;
19  Eff = abs(Ef)*1.2;
20  dl = (Pe/3)*X/(Eff*Vt);
21  ta = asind(dl);
22  disp(ta,'torque angle');
23  Ia = (Eff*complex(cosd(ta),sind(ta))-Vt)/(j*X);
24  disp(abs(Ia),'stator current(A)');
```

```scilab
25 disp(cosd(-atand(imag(Ia)/real(Ia))),'pf');
26
27 Ef=413;
28 Pemax=Ef*Vt/X;
29 Ia=(Ef*complex(cosd(90),sind(90))-Vt)/(j*X);
30 disp(abs(Ia),'stator current(A)');
31 disp(cosd(-atand(imag(Ia)/real(Ia))),'pf');
32
33 Qe=(imag(Ia)/real(Ia))*Pe;disp(Qe,'kVar delivered');
```

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

```scilab
 1 //to calculate armature current, pf ,power angle,
     power , shaft torques ,kVar
 2
 3 clc;
 4 j=sqrt(-1);
 5 P=8000;
 6 Prot=500;
 7 Pmg=P+Prot;
 8 Pein=Pmg;
 9 Ef=750/sqrt(3);
10 Vt=231;
11 Xs=16;
12 dl=asind(Xs*(Pein/3)/(Ef*Vt));
13 Eff=Ef*complex(cosd(-dl),sind(-dl));
14 Ia=(Vt-Eff)/(j*Xs);
15 disp(abs(Ia),'armature current(A)');
16 disp(cosd(atand(imag(Ia)/real(Ia))),'pf');
17 f=50;
18 p=4;
19 n_s=120*f/p;
20 w_s=2*%pi*n_s/60;
21 T=Pein/w_s;disp(T,'torque developed(Nm)');
22 T_s=P/w_s;disp(T_s,'shaft torques(Nm)');
```

```
23
24  Ef =600/ sqrt (3);
25  Ia =(Vt-Ef )/( j*Xs );
26  rr =3*Vt*Ia /1000;
27  disp (rr , 'kVar rating ');
28  c=( abs (Ia )/Vt )/(2* %pi*f );
29  disp (-c , 'capicator rating (F)');
30
31  Ef =300/ sqrt (3);
32  Ia =(Vt-Ef )/( j*Xs );
33  rr =3*Vt*Ia /1000;
34  disp (-rr , 'kVar rating ');
35  L=( Vt/ abs (rr ))/(2* %pi*f );
36  disp (L , 'inductor rating (H)');
37
38  Ia=j *2000/ Vt;
39  Ef =Vt-j*Ia*Xs;
40  disp ( abs (Ef )* sqrt (3) , 'excitation (V)');
```

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

```
1  // find the excitation emf , mech power developed , pf
2
3  clc ;
4  j= sqrt (-1);
5  V =6600;
6  Vt=V/ sqrt (3);
7  r =4*10^6;
8  Ia=r /( sqrt (3)*V );
9  Xs =4.8;
10  // Vt ^2+ Ef ^2 -2* Vt* Efcosd (dl )=( Ia*Xs )^2
11  // after solving
12  // Ef ^2 -7.16* Ef +11.69=0;
13  function [x1 ,x2 ]= quad (a,b,c)
14      d= sqrt (b^2 -4*a*c);
```

```
15      x1=(-b+d)/(2*a);
16      x2=(-b-d)/(2*a);
17 endfunction
18 [Ef1 Ef2]=quad(1,-7.16,11.69);
19 dl=20;
20 disp(Ef1,'excitation(kV)');
21 Pm=3*3.81*Ef1*sind(dl)/Xs;disp(Pm,'power developed(
      MW)');
22 pf1=Pm*10^6/(sqrt(3)*V*Ia);disp(pf1,'pf1');
23
24 disp(Ef2,'excitation(kV)');
25 Pm=3*3.81*Ef2*sind(dl)/Xs;disp(Pm,'power developed(
      MW)');
26 pf2=Pm*10^6/(sqrt(3)*V*Ia);disp(pf2,'pf2');
```

Scilab code Exa 8.16 to find power angle field current

```
1 //to find power angle,field current
2
3 clc;
4 j=sqrt(-1);
5 V=400;
6 Vt=V/sqrt(3);
7 pf=1;
8 Ia=50;
9 Xs=1.3;
10 Ef=Vt-j*Ia*Xs;
11 disp(-atand(imag(Ef)/real(Ef)),'power angle');
12
13 Pm=Vt*Ia*pf;
14 pff=.8;
15 Ia=Pm/(Vt*pff);
16 ang=acosd(pff);
17 Eff=sqrt((Vt*cosd(ang))^2+(Vt*sind(ang)+Ia*Xs)^2);
18 If=.9;
```

```
19  Iff=If*Eff/abs(Ef);
20  disp(Iff,'field current(A)');
```

Scilab code Exa 8.17 to calculate motor eff excitation emf and power angle max pow

```
1  //to calculate motor eff,excitation emf and power
       angle, max power op,corresponding net op
2
3  clc;
4  j=sqrt(-1);
5  Sop=40*1000;
6  Vt=600;
7  Ra=.8;
8  Xs=8;
9
10  Pst=2000;
11  Pmnet=30*1000;
12  Pm_dev=Pst+Pmnet;
13  Ia=Sop/(sqrt(3)*Vt);
14  Poh=3*Ia^2*Ra;
15  Pin=Pm_dev+Poh;
16  eff=(1-(Poh+Pst)/Pin)*100;disp(eff,'motor eff(%)');
17
18  cos_phi=Pin/(sqrt(3)*Vt*Ia);
19  phi=acosd(cos_phi);
20  Ia=Ia*(cosd(phi)+j*sind(phi));
21  Vt=Vt/sqrt(3);
22  Za=Ra+Xs*j;
23  Ef=Vt-Ia*Za;
24  Ef_line=Ef*sqrt(3);disp(Ef_line,'excitation emf(V)')
       ;
25  delta=atand(imag(Ef)/real(Ef));disp(delta,'power
       angle(deg)');
26  IaRa=abs(Ia)*Ra;
27  IaXs=abs(Ia)*Xs;
```

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```
28  AD=Vt*cosd(phi)-IaRa;
29  CD=Vt*sind(phi)+abs(Ia)*Xs;
30  Ef_mag=sqrt((abs(AD))^2+(abs(CD))^2);
31
32  Pm_out_gross=-((abs(Ef_mag))^2*Ra/(abs(Za))^2)+(Vt*
        abs(Ef_mag)/abs(Za));
33  disp(Pm_out_gross,'max power op(W)');
34  power_angle=atand(imag(Za)/real(Za));
35  disp(power_angle,'power angle(deg)');
```

Scilab code Exa 8.18 find the change in the poweer angle

```
1  //find the change in the poweer angle;
2
3  clc;
4  clear
5  j = %i
6  Pe=4000;
7  V=400';
8  pf=.8;dl=acosd(pf);
9  Ia=Pe/(sqrt(3)*V*pf);
10 Vt=V/sqrt(3);
11 Xs=25;
12 Ef=Vt+j*Ia*complex(cosd(-dl),sind(-dl))*Xs;
13 a=atand(imag(Ef)/real(Ef));
14
15 dl=asind((Pe/3)*Xs/(Vt*abs(Ef)));
16 ang=dl+a;
17 disp(ang,'change in power angle(deg)');
```

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

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```
1  //to find no of poles ,MVA rating , prime mover rating
       and op torque
2
3  clc;
4  f=50;
5  n_s=100;
6  P=120*f/n_s;disp(P,'no of poles');
7  r=110;      //MVA rating
8  pf=.8;
9  rr=r/pf;disp(rr,'MVA rating');
10 eff=.971;
11 rt=r/eff;disp(rt,'prime mover rating(MW)');
12 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 re

```
1  //to determine the magnitude of Eg,Em and min value
       of Em to remain m/c in synchronism
2
3  clc;
4  j=sqrt(-1);
5  V_base=400;
6  kva_base=10;
7  MW_base=10;
8  Pm=8/10;
9  Vt=1;
10 pf=.8;
11 Ia=Pm/(Vt*pf);
12 Ia=Ia*complex(pf,sind(acosd(pf)));
13 Em=Vt-j*Ia*pf;
14 Emm=abs(Em)*V_base;
15 dl_m=atand(imag(Em)/real(Em));disp(dl_m,'dl_m(deg)')
       ;
16 Eg=Vt+j*Ia*(pf+.2);
```

```
17  Egg=abs(Eg)*V_base;
18  dl_g=atand(imag(Eg)/real(Eg));disp(dl_g,'dl_g(deg)')
       ;
19  dl_gm=dl_g-dl_m;disp(dl_gm,'relative angle(deg)');
20
21  dl_m=90;
22  Emmin=.8*.8/1;
23  disp(Emmin*V_base,'min value of Em(V)');
```

Scilab code Exa 8.21 to determine armature current pf power angle mech power devel

```
1  //to determine armature current ,pf ,power angle ,mech
       power developed and eff
2
3  clc;
4  j=sqrt(-1);
5  Vt=3300/sqrt(3);
6  Ef=4270/sqrt(3);
7  Pein=750000/3;
8  Zs=.8+j*5.5;
9  a=90-atand(imag(Zs)/real(Zs));
10 dl=asind((Pein-real(Zs)*(Vt/abs(Zs))^2)/((Vt*Ef/abs(
       Zs))))+a;
11 disp(dl,'power angle(deg)');
12 b=Vt-Ef*complex(cosd(-dl),sind(-dl));
13 Ia=b/Zs;
14 disp(abs(Ia),'armature current(A)');
15 phi=atand(imag(Ia)/real(Ia));
16 disp(cosd(phi),'pf');
17 Ef=sqrt(3)*Ef*complex(cosd(-dl),sind(-dl));
18 Pm=sqrt(3)*abs(Ef)*abs(Ia)*cosd(dl+phi);
19 disp(Pm,'mech power developed(W)');
20 Pst=30000;
21 Pmnet=Pm-Pst;
22 eff=Pmnet/(Pein*3);disp(eff*100,'efficiency(%)');
```

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

```
1  //to find armature current ,power factor and power ip
2
3  clc;
4  j=sqrt(-1);
5  Vt=3300/sqrt(3);
6  Ef=4270/sqrt(3);
7  Pein=600000/3;
8  Zs=.8+j*5.5;
9  a=90-atand(imag(Zs)/real(Zs));
10 dl=asind((Pein+real(Zs)*(Ef/abs(Zs))^2)/((Vt*Ef/abs(
       Zs))))-a;
11 disp(dl,'power angle');
12 b=Vt-Ef*complex(cosd(-dl),sind(-dl));
13 Ia=b/Zs;
14 disp(abs(Ia),'armature current(A)');
15 phi=atand(imag(Ia)/real(Ia));
16 disp(cosd(phi),'pf');
17
18 Peinn=sqrt(3)*3300*abs(Ia)*cosd(phi);
19 disp(Peinn,'power ip(W)');
20 loss=Peinn-Pein*3;
21 disp(loss,'ohmic loss(W)');
```

Scilab code Exa 8.23 to calculate pu adjusted sync reactance feild reactance react

```
1  //to calculate pu adjusted sync reactance , feild
       reactance , reactive power op, rotor power angle
2
3  clc;
```

```matlab
 4  j=sqrt(-1);
 5  r=10*10^6;
 6  V_SC=13.8*10^3;
 7  Ia=r/(sqrt(3)*V_SC);
 8  If=226;
 9
10  Iff=842;
11  I_SC=Ia*Iff/If;
12  Xsadj=(V_SC/sqrt(3))/I_SC;
13
14  va_b=10*10^6;
15  v_b=13800;
16  Xspu=Xsadj*va_b/v_b^2;disp(Xspu,'Xs(pu)');
17  Ra=.75;
18  Zs=Ra+j*Xsadj;
19  a=90-atand(imag(Zs)/real(Zs));
20
21  pf=.9;
22  phi=acosd(pf);
23  Pe=8.75*10^6;
24  Qe=Pe*tand(phi);
25  Vt=V_SC/sqrt(3);
26  Ia=(Pe/3)/(Vt*pf);
27  Ef=Vt+abs(Ia)*abs(Zs)*complex(cosd(90-a-phi),sind
        (90-a-phi));
28  Ef=abs(Ef)*sqrt(3);
29  If=Iff*Ef/V_SC;disp(If,'field current(A)');
30  loss=3*abs(Ia)^2*Ra;
31  Pmin=Pe+loss;disp(Pmin,'reactive power op(W)');
32
33  If=842;
34  Voc=7968;
35  Pmin=Pmin/3;
36  dl=asind((Pmin-real(Zs)*(Voc/abs(Zs))^2)/((Voc^2/abs
        (Zs))))+a;
37  disp(dl,'power angle');
38  Q=-(Voc/abs(Zs))^2*imag(Zs)+Voc^2*cosd(dl+a)/abs(Zs)
        ;
```

```
39 disp(Q,'reactive power op(VAR)');
```

Scilab code Exa 8.25 to calculate the excitation emf power angle

```
1 //to calculate the excitation emf,power angle
2
3 clc;
4 Vt=1;
5 Ia=1;
6 pf=.8;phi=acosd(pf);
7 Iaa=Ia*complex(cosd(-phi),sind(-phi));
8 Xq=.5;
9 j=sqrt(-1);
10 Ef=Vt+j*Iaa*Xq;
11
12 dl=17.1;
13 w=phi+dl;
14 Id=Ia*sind(w);
15 Xd=.8;
16 CD=Id*(Xd-Xq);
17 Eff=abs(Ef)+CD;
18 Ef=Vt+j*Iaa*Xd;
19 disp(abs(Ef),'excitation emf(V)');
20 disp(atand(imag(Ef)/real(Ef)),'power angle');
```

Scilab code Exa 8.26 calculate excitation emf

```
1 //calculate excitation emf
2
3 clc;
4 V=3300;
5 Vt=V/sqrt(3);
6 pf=1;
```

```
 7  phi = acosd ( pf ) ;
 8  P =1500*1000;
 9  Ia=P /( sqrt (3) *V*pf ) ;
10  Xq =2.88;
11  Xd =4.01;
12  w=atand (( Vt *0 - Ia * Xq ) /Vt ) ;
13  dl=phi -w ;
14  Id=Ia * sind (w) ;
15  Iq=Ia * cosd (w) ;
16  Ef=Vt * cosd ( dl ) - Id * Xd ;
17  disp ( Ef * sqrt (3) , ' excitation  emf ( line ) (V) ') ;
```

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

```
 1  // to  calculate  generator  terminal  voltage , excitation
        emf , power  angle
 2
 3  clc ;
 4  Xd =1.48;
 5  Xq =1.24;
 6  Xe = .1;
 7  Xdt = Xd + Xe ;
 8  Xqt = Xq + Xe ;
 9
10  MVA =1;
11  Vb =1;
12  pf = .9;
13  phi = acosd ( pf ) ;
14  // ( Vt * cosd ( phi ) ) ^2+( Vt * sind ( phi )+ Ia * Xe ) ^2= Vb ^2;
15  // after  solving
16  // Vt ^2 - .0870* Vt - .99=0;
17  function  [x]= quad (a ,b ,c)
18      d= sqrt (b^2 -4*a*c ) ;
19      x1 =( -b+d ) /(2* a) ;
20      x2 =( -b-d ) /(2* a) ;
```

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```
21      if(x1<Vb)
22          x=x2;
23      else
24          x=x1;
25      end
26  endfunction
27  Vt=quad(1,-.0870,-.99);disp(Vt,'terminal voltage(V)'
        );
28  //after solving
29  phi=20;
30
31  j=sqrt(-1);
32  Ia=1;
33  Iaa=Ia*complex(cosd(-phi),sind(-phi));
34  Ef=Vb+j*Iaa*Xqt;
35  Eff=abs(Ef);
36  dl=atand(imag(Ef)/real(Ef));disp(dl,'power angle');
37  w=dl+phi;
38  Id=Ia*sind(w);
39  Ef=Ef+Id*(Xdt-Xqt);
40  disp(abs(Ef),'excitation emf(V)');
```

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

```
1  //to find max pu power, pu armature current, pu
       reactive power
2
3  clc;
4  Vt=1;
5  Xd=1.02;
6  Xq=.68;
7  Pmmax=Vt^2*(Xd-Xq)/(2*Xd*Xq);disp(Pmmax,'max pu
       power');
8  dl=.5*asind(Pmmax/(Vt^2*(Xd-Xq)/(2*Xd*Xq)));
9
```

```
10  Id=Vt*cosd(dl)/Xd;
11  Iq=Vt*cosd(dl)/Xq;
12  Ia=sqrt(Id^2+Iq^2);disp(Ia,'armature current(pu)');
13
14  Qe=Id*Vt*cosd(dl)+Iq*Vt*sind(dl);disp(Qe,'reactive
        power(pu)');
15
16  pf=cosd(atand(Qe/Pmmax));disp(pf,'pf');
```

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

```
 1  //to calculate power angle,excitation emf,field
        current
 2
 3  clc;
 4  j=sqrt(-1);
 5  MVA_b=300;
 6  kV_b=22;
 7
 8  Pe=250/MVA_b;
 9  pf=.85;
10  Vt=1;
11  Ia=Pe/(pf*Vt);
12  phi=acosd(pf);
13  Iaa=Ia*complex(cosd(-phi),sind(-phi));
14  Xq=1.16;
15  Xd=1.93;
16  Ef=Vt+j*Iaa*Xq;
17  dl=atand(imag(Ef)/real(Ef));disp(dl,'power angle');
18  w=phi+dl;
19  Id=abs(Iaa)*sind(w);
20  Ef=abs(Ef)+Id*(Xd-Xq);
21  disp(Ef*kV_b,'excitation emf(V)');
22
23  If=338;
```

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

Scilab code Exa 8.30 to find max andmin pu field excitation

```
 1  //to find max andmin pu field excitation
 2
 3  clc;
 4  Xd=.71;
 5  Xq=.58;
 6  Xe=.08;
 7  Xdt=Xd+Xe;
 8  Xqt=Xq+Xe;
 9
10  Pe=0;Vt=1;
11  dl=0;
12  phi=90;
13  Ia=1;
14  Iq=0;
15  Id=Ia;
16
17  Ef=Vt+Id*Xdt;
18  Ifmax=Ef;disp(Ifmax,'max field excitation(A)');
19
20
21  Ef=Vt-Id*Xdt;
22  Ifmin=Ef;disp(Ifmin,'min field excitation(A)');
```

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

```
 1  //to calculate synchronising power and torque coeff/
        deg mech shift
 2
 3  clc;
```

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```
 4  clear
 5  j = %i ;
 6  V =11000;
 7  Vt = V / sqrt (3);
 8  P =6*10^6;
 9  Ia = P /( sqrt (3) * V );
10  ohm_b = Vt / Ia ;
11  Xs =.5;
12  Xss = Xs * ohm_b ;
13
14  f =50;
15  P =8;
16  n_s =(120* f / P ) *(2*% pi /60);
17
18  Ef = Vt ;
19  dl =0;
20  Psyn =(% pi /15) *( Ef * Vt / Xss ) * cosd ( dl ); disp ( Psyn , '
        synchronising  power (W) ');
21  Tsyn = Psyn / n_s ; disp ( Tsyn , 'torque  coeff (Nm) ');
22
23  pf =.8;
24  phi = acosd ( pf );
25  Ef = Vt + j * Ia * Xss * complex ( cosd ( - phi ) , sind ( - phi ));
26  dl = atand ( imag ( Ef ) / real ( Ef ));
27  Psyn =(% pi /15) *( abs ( Ef ) * Vt / Xss ) * cosd ( dl ); disp ( Psyn , '
        synchronising  power (W) ');
28  Tsyn = Psyn / n_s ; disp ( Tsyn , 'torque  coeff (Nm) ');
```

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

```
1  //to  calculate  syncronising  power / elec  deg , pu  sync
        torque / mech  deg
2
3  clc ;
4  j = sqrt ( -1);
```

```
5  Xd=.8;
6  Xq=.5;
7  Vt=1;
8  pf=.8;
9  phi=acosd(pf);
10 Ia=1*complex(cosd(phi),sind(phi));
11
12 Ef=Vt-j*Ia*Xq;
13 Eff=abs(Ef);
14 dl=atand(imag(Ef)/real(Ef));
15 w=-dl+phi;
16 Id=abs(Ia)*sind(w);
17 Ef=Eff+Id*(Xd-Xq);
18
19 Psyn=abs(Ef)*Vt*cosd(dl)/Xd+Vt^2*((Xd-Xq)/(Xd*Xq))*
       cosd(2*dl);
20 disp(Psyn*(%pi/180),'syncronising power(pu)/elec deg
       ');
21 f=50;
22 P=12;
23 n_s=(120*f/P)*(2*%pi/60);
24 Tsyn=Psyn/n_s;disp(Tsyn,'pu sync torque/mech deg');
```

Scilab code Exa 8.33 to calculate sync current power and torque

```
1  //to calculate sync current, power and torque
2
3  clc;
4  j=sqrt(-1);
5  P=12000;
6  V=400;
7  pf=.8;
8  Ia=P/(sqrt(3)*V*pf);
9  phi=acosd(pf);
10 Vt=V/sqrt(3);
```

```
11  Xs =2.5;
12  Ef = Vt - j * Ia * complex ( cosd ( phi ) , sind ( phi ) ) * Xs ;
13  tandl =4;
14  Es =2* abs ( Ef ) * sind ( tandl /2) ;
15  Is = Es / Xs ; disp ( Is , 'sync current (A) ') ;
16  dl = atand ( imag ( Ef ) / real ( Ef ) ) ;
17  Ps =3* Vt * Is * cosd ( dl + tandl /2) ; disp ( Ps , 'power (W) ') ;
18  n_s =25*% pi ;
19  T_s = Ps / n_s ;
20  disp ( T_s , 'torque (Nm) ') ;
```

Scilab code Exa 8.34 to calculate value of syncpower

```
1  // to calculate value of syncpower
2
3  clc ;
4  V =6600;
5  E = V / sqrt (3) ;
6
7  P =12;
8  dl =1* P /2;
9
10  r =20000*10^3;
11  I = r /( sqrt (3) * V ) ;
12  Xs =1.65;
13
14  Psy = dl *(% pi /180) * E ^2/ Xs ;
15  disp ( Psy , 'sync power (W) ') ;
```

Scilab code Exa 8.35 to determine op current and pf

```
1  // to determine op current and pf
2
```

```
3  clc;
4  P1=400*10^3;
5  P2=400*10^3;
6  P3=300*10^3;
7  P4=800*10^3;
8  pf1=1;
9  pf2=.85;
10 pf3=.8;
11 pf4=.7;
12 phi1=acosd(pf1);
13 phi2=acosd(pf2);
14 phi3=acosd(pf3);
15 phi4=acosd(pf4);
16 P=P1+P2+P3+P4;
17 Q1=P1*tand(phi1);
18 Q2=P2*tand(phi2);
19 Q3=P3*tand(phi3);
20 Q4=P4*tand(phi4);
21 Q=Q1+Q2+Q3+Q4;
22
23 I=100;
24 pf=.9;
25 V=6600;
26 P_A=sqrt(3)*V*I*pf;
27 P_B=P-P_A;
28 Q_A=P_A*tand(acosd(pf));
29 Q_B=Q-Q_A;
30 phi=atand(Q_B/P_B);
31 pf=cosd(phi);disp(pf,'pf');
32 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

```
1  //to find the pf and current supplied by the m/c
2
```

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```
3  clc;
4  P=50000;
5  pf=.8;
6  phi=acosd(pf);
7  Q=P*tand(phi);
8  P1=P/2;
9  pf1=.9;
10 phi1=acosd(pf1);
11 Q1=P1*tand(phi1);
12 P2=P/2;
13 Q2=Q-Q1;
14 phi2=atand(Q2/P2);
15 pf=cosd(phi2);disp(pf,'pf');
16 V_L=400;
17 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

```
1  //to  find  initial  current , current  at  the  end  of  2
       cycles  and  at  the  end  of  10 s
2
3  clc;
4  Ef=1;
5  Xd2=.2;
6  I2=Ef/Xd2;
7  r=100*10^6;
8  V=22000;
9  I_b=r/(sqrt(3)*V);
10 I2=I2*I_b;disp(I2,'initial  current(A)');
11
12 Xd1=.3;
13 I1=Ef/Xd1;
14 Xd=1;
15 I=Ef/Xd;
```

```
16
17  tau_dw =0.03;
18  tau_f =1;
19
20  function [a]=I_sc(t)
21      a=(I2-I1)*exp(-t/tau_dw)+(I1-I)*exp(-t/tau_f)+1;
22  endfunction
23  //2 cycles=0.04s
24  disp(I_sc(.2867)*I_b,'current at the end of 2 cycles
        (A)');
25  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 e

```
1  //to calculate sync reactance,voltage regulation,
        torque angle, ele power developed, voltage and
        kva rating
2
3  clc;
4  r=1000*10^3;
5  V=6600;
6  Ia=r/(sqrt(3)*V);
7  pf=.75;
8  phi=-acosd(pf);
9  Vt=V/sqrt(3);
10 Ef=11400/sqrt(3);
11 //Ef*complex(cosd(dl),sind(dl))=Vt+j*Xs*Ia*complex(
        cosd(phi),sind(phi))
12 //after solving
13 //6.58*cosd(dl)=3.81+.058*Xs;
14 //6.58*sind(dl)=.0656*Xs;
15 //so after solving
16 //cosd(dl-phi)=.434;
17 dl=acosd(.434)+phi;
18
```

```
19  Xs=Ef*sind(dl)/65.6;disp(Xs,'sync reactance(ohm)');
20  vr=Ef*sqrt(3)/V-1;disp(vr,'voltage regulation(%)');
21  disp(dl,'torque angle(deg)');
22  P=3*Ef*Ia*cosd(dl-phi);disp(P,'ele power developed(W
      )');
23
24  volr=V/sqrt(3);disp(volr,'voltage rating(V)');
25  ir=Ia*sqrt(3);disp(ir,'current rating(A)');
26  r=sqrt(3)*volr*ir;disp(r,'VA rating');
```

Scilab code Exa 8.40 to determine mc and pf

```
1  //to determine m/c and pf
2
3  clc;
4  j=sqrt(-1);
5  P=230*10^6;
6  V=22000;
7  pf=1;
8  Ia=P/(sqrt(3)*V*pf);
9  Vt=V/sqrt(3);
10  Xs=1.2;
11  Ef=Vt+j*Xs*Ia;
12  //if Ef is inc by 30%
13  Ef=1.3*abs(Ef);
14
15  dl=asind((P/3)*Xs/(Ef*Vt));
16  Ia=((Ef*complex(cosd(dl),sind(dl)))-Vt)/(j*Xs);
17  disp(abs(Ia),'m/c current(A)');
18  disp(cosd(atand(imag(Ia)/real(Ia))),'pf');
19
20  P=275*10^6;
21  dl=asind((P/3)*Xs/(Ef*Vt));
22  Ia=((Ef*complex(cosd(dl),sind(dl)))-Vt)/(j*Xs);
23  disp(abs(Ia),'m/c current(A)');
```

```
24 disp(cosd(atand(imag(Ia)/real(Ia))),'pf');
```

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

```
1  //to calculate excitation emf,torque angle, eff,
       shaft op
2
3  clc;
4  j=sqrt(-1);
5  Va=.8;
6  Xa=5.5;
7  Xs=Va+j*Xa;
8  V=3300;
9  Ia=160;
10 pf=.8;
11 loss=30000;
12 phi=acosd(pf);
13 Ef=V/sqrt(3)-Xs*Ia*complex(cosd(-phi),sind(-phi));
       disp(abs(Ef),'excitation emf(V)');
14 dl=atand(imag(Ef)/real(Ef));disp(dl,'torque angle(
       deg)');
15 P_mech=3*abs(Ef)*Ia*cosd(-phi-dl);
16 op_sft=P_mech-loss;disp(op_sft,'shaft op(W)');
17 Pip=sqrt(3)*V*Ia*pf;
18 eff=op_sft/Pip;disp(eff*100,'efficiency(%)');
```

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

```
1  //to caculate generator current,pf, real power,
       ecitation emf
2
3  clc;
4  clear
```

```
 5  j = %i;
 6  r=500*10^6;
 7  V=22000;
 8  Ia=r/(sqrt(3)*V);disp(Ia,'generator current(A)');
 9  Vt=V/sqrt(3);
10  Zb=Vt/Ia;
11  MVA_b=500;
12  MW_b=500;
13  Xsg=1.57;
14  Xb=.4;
15  Xb=Xb/Zb;
16
17  rr=250;
18  rr=rr/MVA_b;
19  Vb=1;
20  Vt=1;
21  Ia=.5;
22  phi=asind(Xb*Ia/2);
23  pf=cosd(phi);disp(pf,'pf');
24  Pe=rr*pf;disp(Pe,'real power(pu)');
25  Eg=Vt+j*Xsg*rr**complex(cosd(-phi),sind(-phi));
26  Egg=abs(Eg)*V;disp(Egg,'excitation emf(V)');
27
28
29  rr=500;
30  rr=rr/MVA_b;
31  Vb=1;
32  Vt=1;
33  Ia=1;
34  phi=asind(Xb*Ia/2);
35  pf=cosd(phi);disp(pf,'pf');
36  Pe=rr*pf;disp(Pe,'real power(pu)');
37  Eg=Vt+j*Xsg*rr*complex(cosd(-phi),sind(-phi));
38  Egg=abs(Eg)*V;disp(Egg,'excitation emf(V)');
```

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

```
1  //to clculate pf angle, torque angle,equivalent
       capicitor and inductor value
2
3  clc;
4  of1=250;
5  scr=.52;        //short ckt ratio
6  of2=of1/scr;
7  r=25*10^6;
8  V=13000;
9  Ia=r/(sqrt(3)*V);
10 Isc=Ia*of1/of2;
11 Xs=V/(sqrt(3)*Isc);
12 Xb=V/(sqrt(3)*Ia);
13 Xsadj=Xs/Xb;
14
15 f=50;
16 If=200;
17 Ef=V*If/of1;
18 Vt=V/sqrt(3);
19 Ia=(Vt-Ef/sqrt(3))/Xs;
20 dl=0;disp(dl,'torque angle(deg)');
21 pf=90;disp(pf,'pf angle(deg)');
22 L=(V/(sqrt(3)*Ia))/(2*%pi*f);
23 disp(L,'inductor value(H)');
24
25 If=300;
26 Eff=V*If/of1;
27 Vt=Ef/sqrt(3);
28 Ia=(Eff/sqrt(3)-Vt)/Xs;
29 dl=0;disp(dl,'torque angle(deg)');
30 pf=90;disp(pf,'pf angle(deg)');
31 c=1/((V/(Ia))*(2*%pi*f));
32 disp(c,'capacitor value(F)');
```

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

```
1 //to determine Xs(saturated),scr,Xs(unsat)and If,
    generator current
2
3 clc;
4 MVA_b=400;
5 kV_b=22;
6 Ib=MVA_b/(sqrt(3)*kV_b);
7 ohm_b=kV_b/(sqrt(3)*Ib);
8
9 If=1120;
10 Voc=kV_b/sqrt(3);
11 Isc=13.2;
12 Xssat=Voc/Isc;disp(Xssat,'Xs(saturated)(ohm)');
13 Xss=Xssat/ohm_b;disp(Xss,'Xs(saturated)(pu)');
14 scr=1/Xss;disp(scr,'SCR');
15 Isc=Ib;
16 Voc=24.4/sqrt(3);
17 Xsunsat=Voc/Isc;disp(Xsunsat,'Xs(unsaturated)(ohm)')
    ;
18 Xsuns=Xsunsat/ohm_b;disp(Xsuns,'Xs(unsaturated)(pu)'
    );
19 Iff=If*scr;disp(Iff,'generator current(A)');
```

Scilab code Exa 8.45 find motor pf

```
1 //find motor pf
2
3 clc;
4 j=sqrt(-1);
5 V=6600;
```

```
 6  Vt=V/sqrt(3);
 7  pf=.8;
 8  phi=acosd(pf);
 9  P=800000;
10  Ia=P/(sqrt(3)*V*pf);
11  Zs=2+20*j;
12  Ef=Vt-Zs*Ia*complex(cosd(phi)+sind(phi));
13  Pip=1200*10^3;
14  theta=atand(imag(Zs)/real(Zs));
15  dl=acosd((real(Ef)^2*cosd(theta)/abs(Zs)-P/3)/(real(
       Ef)*abs(Ef)/abs(Zs)))-theta;
16
17  Ia=(real(Ef)-abs(Ef)*complex(cosd(-dl),sind(-dl)))/
       Zs;
18  phi=atand(imag(Ia)/real(Ia));
19  disp(cosd(phi),'pf');
```

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

```
 1  //to find exciting emf neglecting saliency and
       accounting saliency
 2
 3  clc;
 4  j=sqrt(-1);
 5  Xd=.12/3;
 6  Xq=.075/3;
 7
 8  disp('neglecting saliency');
 9  Xs=Xd;
10  V=440;
11  pf=.8;
12  phi=acosd(pf);
13  Vt=V/sqrt(3);
14  Ia=1000;
15  Ef=Vt+j*Xs*Ia*complex(cosd(-phi),sind(-phi));
```

```
16  disp(abs(Ef)*sqrt(3),'excitation emf(line)(V)');
17  disp('accounting saliency');
18  w=atand((Vt*sind(phi)+Ia*Xq)/(Vt*cosd(phi)));
19  dl=w-phi;
20  Ef=Vt*cosd(dl)+Ia*sind(dl)*Xd;
21  disp(abs(Ef)*sqrt(3),'excitation emf(line)(V)');
```

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

```
1  //calculate excitation emf,max load motor supplies,
       torque angle
2
3  clc;
4  Xd=23.2;
5  Xq=14.5;
6  V=6600;
7  pf=.8;
8  phi=acosd(pf);
9  Vt=V/sqrt(3);
10  r=1500*1000;
11  Ia=r/(sqrt(3)*V)
12  w=atand((Vt*sind(-phi)-Ia*Xq)/(Vt*cosd(phi)));
13  dl=-phi-w;disp(dl,'torque angle');
14  Ef=Vt*cosd(dl)-Ia*sind(w)*Xd;
15  disp(Ef,'excitation emf(V)');
16
17  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 g

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

```
 2
 3  clc;
 4  loadtot =260;
 5  r =125;
 6  pf = .84;
 7  genfl=r*pf;
 8  sld =75;     //supply load
 9  n =3;      //no of generators
10  ls=loadtot -n* sld;
11  m = -5/ genfl;
12  f =50;
13  ff=f -m* sld; disp (ff, 'set  freq (Hz) ');
14  c=f -m* ls; disp (c, 'set  freq (Hz)  supplied  from  swing
       generator ');
15  nld=sld +50/4;
16  c=ff+m* nld; disp (c, 'new  system  freq (Hz) ');
17  rld =310 -n* sld;
18  c=f -m* rld; disp (c, 'set  freq (Hz)  of  swing  generator ');
19  nld =310/n;
20  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 effici

```
1  // to campute cu loss in rotoe windings, input to
       the motor, efficiency
2
3  clc;
4  f_s =120/60;          // cycles/min
5  f =50;
6  s=f_s/f;
7  n_s =1000;
8  n =(1-s)*n_s;
9  w=n*2*%pi/60;
10 T =160;
11 P=T*w;
12 T_L =10;
13 P_m =(T+T_L)*w;
14 cu =P_m*(s/(1-s));     disp (cu ,'rotor cu loss(W) ');
15
16 P_sl =800;     // stator loss
17 P_in =P_m+cu+P_sl;     disp(P_in ,'power i/p to motor(W
       )');
18
19 eff =P/P_in;
```

```
20  disp ( eff *100 , ' e f f i c i e n c y (%) ' ) ;
```

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

```
1  // to  calculate  torque , resitance  to  be  added  to  rotor
        ckt
2
3  clc ;
4  clear
5  s  =  0.05;
6  f =50;
7  P =6;
8  n_s =120* f / P ;
9  w_s =2*% pi * n_s /60;
10  n =875;
11  s_maxT =( n_s - n ) / n_s ;
12  R_2 =.25;
13  X_2 = R_2 / s_maxT ;
14  T_max =10;
15  // v=V / a
16  v = sqrt (( T_max * w_s * X_2 ) /(3*.5) ) ;
17  T =((3) * v ^2*( R_2 / s ) ) /( w_s *(( R_2 / s ) ^2+( X_2 ) ^2) ) ;
18  disp ( T , ' t o r q u e (Nm) ' ) ;
19
20  // from  eqn ( T_start / T_max )=(R2+Rext ) *(X2 /.5) /(( R2+
        Rext ) ^2+X2^2)
21  // after  solving
22  // Rt^2 −6.67* Rt+4=0
23  function  [ x ]= quad ( a , b , c )
24      d = sqrt ( b ^2-4* a * c ) ;
25      x1 =( - b + d ) /(2* a ) ;
26      x2 =( - b - d ) /(2* a ) ;
27      if ( x1 > x2 )
28          x = x2 ;
29      else
```

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

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

```
1   //to find slip at max torque,full load slip and
        rotor current at starting
2
3   clc;
4   // Tfl=(3/w_s)*(V^2*Rs/s_fl)/((R2/s_fl)^2+X2^2);      (
        i )
5   //Ts=(3/w_s)*(V^2*R2)/(R2^2+X2^2);      (ii)
6   //Tmax=(3/w_s)*(.5*V^2)/X2^2;      (iii)
7   //Tmax/Ts=2;      k=R2/X2;      (iii)/(ii)and solving
8   //k^2-4*k+1=0;
9   function [x]=quad(a,b,c)
10      d=sqrt(b^2-4*a*c);
11      x1=(-b+d)/(2*a);
12      x2=(-b-d)/(2*a);
13      if(x1>x2)
14          x=x2;
15      else
16          x=x1;
17      end
18  endfunction
19  k=quad(1,-4,1);
20  disp(k,'s_max_T');
21
22  //(iii)/(i)and solving
23  // s_fl^2-1.072*s_fl+.072=0
24  s_fl=quad(1,-1.072,.072);
```

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```
25  disp(s_fl,'s_fl');
26
27  //a=I2_start/I2_fullload
28  a=sqrt((k/s_fl)^2+1)/(k^2+1);
29  disp(a,'I2_start/I2_fullload');
```

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

```
1  //to calculate stator current,pf, net mech o/p,
       torque, motor performance
2
3  clc;
4  j=sqrt(-1);
5  Vt=400;
6  P=6;
7  f=50;
8  Inl=7.5;
9  Pnl=700;
10  disp('block rotor test results');
11  Vbr=150;
12  Ibr=35;
13  Pinbr=4000;
14  R1=.55;disp(R1,'R1(ohm)');
15  k=1/.5;
16  s=0.04;
17  Zbr=Vbr/(sqrt(3)*Ibr);
18  Rbr=Pinbr/(3*Ibr^2);
19  Xbr=sqrt(Zbr^2-Rbr^2);
20  X1=Xbr/(1+.5);disp(X1,'X1(ohm)');
21  X2=Xbr-X1;disp(X2,'X2(ohm)');
22  disp('no load test results');
23  Zo=Vt/(sqrt(3)*Inl);
24  Ro=Pnl/(3*Inl^2);
25  Xo=sqrt(Zo^2-Ro^2);
26  Xm=Xo-X1;disp(Xm,'Xm(ohm)');
```

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```
27  R2 =( Rbr - R1 ) *(( Xm + X2 )/ Xm )^2; disp ( R2 , 'R2 ( ohm ) ');
28  Zf =1/(((1/( j * Xm ))+(1/(( R2 / s )+ j * X2 ))));
29  Rf = real ( Zf );
30  Xf = imag ( Zf );
31  Zin = R1 + j * X1 + Zf ;
32  I1 = Vt /( sqrt (3) * Zin );
33  Pin = sqrt (3) * Vt * abs ( I1 )* cosd ( atand ( imag ( I1 )/ real ( I1 ))
        ); disp ( Pin , 'Pin (W) ');
34  Pg =3* abs ( I1 )^2* Rf ; disp ( Pg , 'Pg (W) ');
35  Pm =(1 - s )* Pg ; disp ( Pm , 'Pm (W) ');
36  Prot = Pnl -3* Inl ^2* R1 ; disp ( Prot , 'Prot (W) ');
37  Pout = Pm - Prot ; disp ( Pout , 'Pout (W) ');
38  w_s =1000*2* %pi /60;
39  Tnet = Pout /((1 - s )* w_s ); disp ( Tnet , 'Tnet (Nm) ');
40  eff = Pout *100/ Pin ; disp ( eff , 'eff (%) ');
```

Scilab code Exa 9.5 to determine ckt model parameters parameters of thevenin equiv

```
1  // to determine ckt model parameters , parameters of
       thevenin equivalent , max torque and slip , stator
       current , pf and eff
2
3  clc ;
4  j = sqrt ( -1) ;
5  // NL test
6  V =3300;
7  f =50;
8  Inl =5;
9  Po =2500;
10 Zo = V /( sqrt (3) * Inl );
11 Ro = Po /(3* Inl ^2) ; disp ( Ro , 'Ro ( ohm ) ');
12 Xo = sqrt ( Zo ^2 - Ro ^2) ; disp ( Xo , 'Xo ( ohm ) ');
13 // BR test
14 V_BR =400;
15 I_BR =27;
```

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```
16  ff=15;
17  P_BR=15000;
18  Z_BR=V_BR/(sqrt(3)*I_BR);
19  R_BR=P_BR/(3*I_BR^2);
20  X_BR=sqrt(Z_BR^2-R_BR^2);
21  x1=X_BR/2;      //at 15 Hz
22  X1=x1*f/ff;       //at 50Hz
23  disp(X1,'X1(ohm)');
24  Xm=Xo-X1;disp(Xm,'Xm(ohm)');
25  R1=3.75;
26  R2=(R_BR-R1)*((Xm+X1)/Xm)^2;disp(R2,'R2(ohm)');
27
28  V_TH=(V/sqrt(3))*complex(cosd(0),sind(0))*complex(0,
      Xm)/complex(R1,X1+Xm);
29  disp(V_TH,'V_TH(V)');
30  Z_TH=complex(0,Xm)*complex(R1,X1)/complex(R1,X1+Xm);
31  disp(real(Z_TH),'R_TH(ohm)');
32  disp(imag(Z_TH),'X_TH(ohm)');
33
34  a=(sqrt(real(Z_TH)^2+(X1+imag(Z_TH))^2));
35  s_max_T=R2/a;
36  n_s=1000;
37  Z_tot=complex(real(Z_TH)+a,X1+imag(Z_TH));
38  I2=abs(V_TH)/abs(Z_tot);
39  T_max=3*(I2^2)*R2/(s_max_T*(2*%pi*n_s/60));disp(
      T_max,'T_max(Nm)');
40
41  Z_f=complex(0,Xm)*complex(81.25,X1)/complex(81.25,X1
      +Xm);
42  Z_in=Z_f+complex(R1,X1);
43  I1=V/(sqrt(3)*abs(Z_in));
44  pf=cosd(atand(imag(Z_in)/real(Z_in)));
45  s=.04;
46  Pmechg=(1-s)*3*I1^2*real(Z_f);
47  Prot=Po-Inl^2*R1;
48  Pip=sqrt(3)*V*I1*pf;
49  Pop=Pmechg-Prot;
50  eff=Pop/Pip;disp(eff,'efficiency');
```

```
51  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

```
 1  //to  calculate  starting  torque  and  current , full  load
        current , pf ,  torque  ,  internal  and  overall  eff ,
      slip  and  max  torque
 2
 3  clc ;
 4  R1 =.3;
 5  R2 =.25;
 6  X1 =.6;
 7  X2 =.6;
 8  Xm =35;
 9  Prot =1500;
10  V =231;
11  Z_TH = complex (0 , Xm ) * complex ( R1 , X1 ) / complex ( R1 , X1 + Xm ) ;
12  V_TH =( V * complex (0 , Xm ) ) / complex ( R1 , X1 + Xm ) ;
13  n_s =1500;
14  w_s =2* % pi * n_s /60;
15
16  s =1;
17  Z_f = complex (0 , Xm ) * complex ( R2 , X2 ) / complex ( R2 , X2 + Xm ) ;
18  R_f = real ( Z_f ) ;
19  Z_in = Z_f + complex ( R1 , X1 ) ;
20  I1 = V / abs ( Z_in ) ; disp ( I1 , 'starting  current (A) ') ;
21  Tstart =3* I1 ^2* R_f / w_s ; disp ( Tstart , 'starting  torque (
      Nm) ') ;
22
23  n =1450;
24  s =1 - n / n_s ;
25  a = R2 / s ;
26  Z_f = complex (0 , Xm ) * complex ( a , X2 ) / complex ( a , X2 + Xm ) ;
27  R_f = real ( Z_f ) ;
```

```
28  Z_in=Z_f+complex(R1,X1);
29  I1=V/abs(Z_in);disp(I1,'full load current(A)');
30  pf=cosd(atand(imag(Z_in)/real(Z_in)));disp(pf,'pf');
31  P_G=3*I1^2*R_f;
32  Popg=P_G*(1-s);
33  Pop=Popg-Prot;
34  Tnet=Pop/((1-s)*w_s);disp(Tnet,'net torque(Nm)');
35  Vt=400;
36  Pip=sqrt(3)*Vt*I1*pf;
37  eff=Pop/Pip;disp(eff*100,'efficiency(%)');
38  int_eff=Popg/Pip;disp(int_eff*100,'internal eff(%)')
        ;
39
40  s_max_T=1/(sqrt(real(Z_TH)^2+(imag(Z_TH)+X1)^2)/R2);
        disp(s_max_T,'max slip');
41  Z_tot=Z_TH+complex(R2/s_max_T,X2);
42  I2=abs(V_TH)/abs(Z_tot);
43  T_max=3*I2^2*(R2/s_max_T)/w_s;
44  disp(T_max,'max torque(Nm)');
```

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

```
1  //to determine the line current ,pf, power ip, shaft
       torque, mech op and efficiency
2
3  clc;
4  R1=1.4;
5  R2=.6;
6  X1=2;
7  X2=1;
8  Xm=50;
9  V=400;
10 Prot=275;
11 n_s=1000;
12 w_s=2*%pi*n_s/60;
```

```matlab
13
14  disp('slip=0.03');
15  s=0.03;
16  I2=(V/sqrt(3))/complex(R1+R2/s,X1+X2);
17  Im=(V/sqrt(3))/(Xm*complex(cosd(90),sind(90)));
18  I1=Im+I2;
19  I_L=abs(I1);disp(I_L,'line current(A)');
20  pf=cosd(atand(imag(I1)/real(I1)));disp(pf,'pf');
21  Pip=sqrt(3)*V*abs(I1)*cosd(atand(imag(I1)/real(I1)))
      ;disp(Pip,'power i/p(W)');
22
23  P_G=3*abs(I2)^2*R2/s;
24  Pmechg=(1-s)*P_G;disp(Pmechg,'mech power op(W)');
25  Popnet=Pmechg-Prot;
26  Tnet=Popnet/(w_s*(1-s));disp(Tnet,'shaft torque(Nm)'
      );
27  eff=Popnet/Pip;disp(eff,'efficiency');
28
29  disp('slip= -0.03');
30  s=-0.03;
31  I2=(V/sqrt(3))/complex(R1+R2/s,X1+X2);
32  Im=(V/sqrt(3))/(Xm*complex(cosd(90),sind(90)));
33  I1=-(Im+I2);
34  I_L=abs(I1);disp(I_L,'line current(A)');
35  pf=cosd(atand(imag(I1)/real(I1)));disp(pf,'pf');
36  Pip=sqrt(3)*V*abs(I1)*cosd(atand(imag(I1)/real(I1)))
      ;disp(Pip,'power i/p(W)');
37
38  P_G=3*abs(I2)^2*R2/s;
39  Pmechop=(1-s)*P_G;
40  Pmechipnet=-Pmechop;
41  Pmechipg=Pmechipnet+Prot;disp(Pmechipg,'mech power
      op(W)');
42  Tnet=Pmechipg/(w_s*(1-s));disp(Tnet,'shaft torque(Nm
      )');
43  eff=Pip/Pmechipg;disp(eff,'efficiency');
44
45  disp('slip= 1.2');
```

```
46  s =1.2;
47  I2 =( V/ sqrt (3) )/ complex ( R1+R2/s ,X1+X2);
48  Im =( V/ sqrt (3) )/( Xm * complex ( cosd (90) , sind (90) ));
49  I1 = Im + I2 ;
50  I_L = abs ( I1 ); disp ( I_L , ' line  current (A) ');
51  pf = cosd ( atand ( imag ( I1 )/ real ( I1 ))); disp ( pf , 'pf ');
52  Pip = sqrt (3) * V* abs ( I1 )* pf ; disp ( Pip , ' power  i /p(W) ');
53
54  P_G =3* abs ( I2 )^2*.5/ s;
55  Pmechg =(1 - s)* P_G ; disp ( Pmechg , ' mech  power  op(W) ');
56  Pmechabs = - Pmechg ;
57  n=n_s *(1 - s);
58  w =2*% pi *n /60;
59  Tnet = Pmechg /w; disp ( Tnet , ' torque  developed (Nm) ');
60  P= Pmechabs + Pip ; disp (P , ' power  disipated (W) ');
```

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

```
1  // to  calculate  max  torque  and  slip ,  starting  torque
2
3  clc ;
4  k =5;       // k=I_s / I_fl
5  s_fl =0.04;
6  s_max_T = sqrt (( s_fl ^2*(1 - k ^2) )/(( k* s_fl )^2 -1) ); disp (
       s_max_T , ' slip ');
7  T_max =.5*( s_max_T ^2+ s_fl ^2) /( s_fl * s_max_T ); disp (
       T_max , ' max  torque (pu) ');
8
9  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 resist

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```
1  //to find starting current and torque, necessary
      exteranl resistance and corresponding starting
      torque
2
3  clc;
4  f=50;
5  R2=.1;
6  X2=2*%pi*f*3.61*10^-3;
7  a=3.6;
8  R22=a^2*R2;
9  X22=a^2*X2;
10 V=3000;
11 n_s=1000;
12 w_s=2*%pi*n_s/60;
13 I_s=(V/sqrt(3))/sqrt(R22^2+X22^2);disp(I_s,'starting
      current(A)');
14 T_s=(3/w_s)*(V/sqrt(3))^2*R22/(R22^2+X22^2);disp(T_s
      ,'torque(Nm)');
15
16 Iss=30;
17 Rext=sqrt(((V/sqrt(3)/Iss)^2-X22^2)-R22);
18 disp(Rext,'external resistance(ohm)');
19 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 s

```
1  //find line current and starting torque with direct
      switching, stator resistance starting,
      autotransformer starting, star delta starting,
      autotransformer ratio give 1 pu
2
3  clc;
4  //I_s/I_fl=6;
5  s_fl=0.05;
```

```
6  disp('by direct switching');
7  Is=6;disp(Is,'line current(pu)');
8  T=Is^2*s_fl;disp(T,'torque(pu)');
9
10 disp('by stator resistance starting');
11 Is=2;disp(Is,'line current(pu)');          //given
12 T=Is^2*s_fl;disp(T,'torque(pu)');
13
14 disp('by autotransformer starting');
15 x=2/6;
16 Is_motor=2;
17 Is=Is_motor*x;disp(Is,'line current(pu)');
18 T=Is^2*s_fl;disp(T,'torque(pu)');
19
20 disp('by star delta starting');
21 Is=(1/3)*6;disp(Is,'line current(pu)');
22 T=Is^2*s_fl*3;disp(T,'torque(pu)');
23
24 disp('by autotransformer starting');
25 Ts=1;
26 x=sqrt(Ts/((6^2)*s_fl));disp(x,'x');
```

Scilab code Exa 9.13 to find resistance added to ckt

```
1  //to find resistance added to ckt
2
3  clc;
4  Rrot=.061;
5  R2=Rrot/2;
6  f=50;
7  P=12;
8  w_s=(120*f/P)*(2*%pi/60);
9  s=0.045;
10 w=(1-s)*w_s;
11 P=200*10^3;
```

```
12  T_fan=P/w;
13  I2=sqrt(T_fan*w_s*s/(3*R2));
14  E2=I2*R2/s;
15  n=450;
16  ww=2*%pi*n/60;
17  nn=500;
18  ss=(nn-n)/nn;
19  Tnew=T_fan*(ww/w)^2;
20  Rt=(3/w_s)*(E2*ss)^2/(ss*Tnew);
21  Rext=Rt-R2;disp(Rext,'external resistance(ohm)');
```

Scilab code Exa 9.14 to find resistance added to ckt

```
1  //to find resistance added to ckt
2
3  clc;
4  n_s=1500;
5  w_s=2*%pi*n_s/60;
6  n=1250;
7  s=1-n/n_s;
8  //Im=(1/3)*(0.3+.25/s+j*1.83)ohm/ph
9  T=150;
10  V=440;
11  //T=(3/w_s)*(V^2*(R_2t/s))/((.1+(R_2t/s))^2+(X1+X2)
        ^2);
12  //after solving R_2t^2-1.34*R_2t+0.093=0
13  function [x]=quad(a,b,c)
14      d=sqrt(b^2-4*a*c);
15      x1=(-b+d)/(2*a);
16      x2=(-b-d)/(2*a);
17      if(x1>x2)
18          x=x1;
19      else
20          x=x2;
21      end
```

```
22  endfunction
23  [x]=quad(1,-1.34,0.093);
24  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

```
 1  //to  calculate  the  min  resistance  to  be  added  and
        speed  of  the  motor
 2
 3  clc;
 4  V=400;
 5  a=2.5;
 6  X2=.4;
 7  R2=0.08;
 8  n_s=750;
 9  w_s=2*%pi*n_s/60;
10  T=250;
11  //T=(3/w_s)*((V/sqrt(3))/a)*R2t/(R2t^2+X2^2);
12  //after  solving
13  //R2t^2-1.304*R2t+0.16=0
14  function  [x1,x2]=quad(a,b,c)
15      d=sqrt(b^2-4*a*c);
16      x1=(-b+d)/(2*a);
17      x2=(-b-d)/(2*a);
18  endfunction
19  [x1  x2]=quad(1,-1.304,0.16);
20      if(x1>x2)
21          R2t=x2;
22      else
23          R2t=x1
24      end
25  Rext=R2t-R2;
26  disp(Rext,'external  resistance(ohm)');
27
28  //T=(3/w_s)*((V/sqrt(3))/a)*(R2t/s)/((R2t/s)^2+X2^2)
```

```
          ;
29  // after solving
30  // (R2t/s)^2-1.304*(R2t/s)+0.16=0
31  [x1 x2]=quad(1,-1.304,0.16);
32  s=x2/x1;
33  n=n_s*(1-s);
34  disp(n,'speed(rpm)');
35
36  //T=(3/w_s)*((V/sqrt(3))/a)*(R2/s)/((R2/s)^2+X2^2);
37  // after solving
38  // (R2/s)^2-1.304*(R2/s)+0.16=0
39  [x1 x2]=quad(1,-1.304,0.16);
40  R2=0.08;
41  s1=R2/x1;
42  s2=R2/x2;
43  if(s1>s2)
44          ss=s2;
45      else
46          ss=s1
47      end
48  n=n_s*(1-ss);
49  disp(n,'speed(rpm)');
```

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

```
1  //to find the ratio of currents and torques at the
        starting ,V2/V1
2
3  clc;
4  f1=50;
5  f2=60;
6  f=f2/f1;
7  V=1;        //V=V2/V1
8  s_max_T=0.2;
9  // Is=I_s2/I_s1
```

```
10 Is=V*sqrt((s_max_T^2+1)/(s_max_T^2+f^2));
11 disp(Is,'ratio of currents at starting');
12 //Ts=T_s2/T_s1
13 Ts=V^2*((s_max_T^2+1)/(s_max_T^2+f^2));
14 disp(Ts,'ratio of torques at starting');
15 //Tmax=Tmax2/Tmax1
16 Tmax=V^2/f^2;
17 disp(Tmax,'ratio of max torques');
18 Vr=sqrt(1/sqrt((s_max_T^2+1)/(s_max_T^2+f^2)));
19 disp(Vr,'V2/V1');
```

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

```
1 //to calculate ratio of torques at starting and at
      slip =0.05
2
3 clc;
4 R1=0.01;
5 X1=.5;
6 R2=0.05;
7 X2=.1;
8 Ts=((R1^2+X1^2)/(R2^2+X2^2))*(R2/R1);
9 disp(Ts,'Tso/Tsi');
10
11 s=0.05;
12 T=(((R1/s)^2+X1^2)/((R2/s)^2+X2^2))*(R2/R1);
13 disp(T,'To/Ti');
```

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

```
1 //to compute acc time and value of rotor resistance
2
3 clc;
```

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```
 4  s =1 -.96;      // load  is  brought  to  .96  of  n_s
 5  s_max_T=sqrt((1-s^2)/(2*log(1/s)));
 6  R =1.5;
 7  R2_opt=R*s_max_T;disp(R2_opt,'rotor  resistance(ohm)'
       );
 8  n =1000;
 9  w_s=2*%pi*n/60;
10  V =415;
11  Tmax=(3/w_s)*(.5*(V/sqrt(3))^2)/R;
12  J =11;
13  t_A=(J*w_s/(2*Tmax))*((1-s^2)/(2*s_max_T)+s_max_T*
       log(1/s));
14  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 to

```
1  // 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
2
3  clc;
4  R_lm=3;
5  X_lm=5;
6  R_2=1.5;
7  X_2=2;
8  s=1-.97;            // slip
9  a=complex(R_2/s,X_2);
10 b=complex(R_2/(2-s),X_2);
11 c=abs(a)/abs(b);
12 disp(c,'E_mf/E_mb');
13 a=(1/2)*complex((R_lm+R_2/s),(X_lm+X_2));
14 b=(1/2)*complex((R_lm+R_2/(2-s)),(X_lm+X_2));
15 c=abs(a)/abs(b);
16 disp(c,'V_f/V_b');
17 d=(2-s)/s;
18 disp(d,'T_f/T_b');
19 Z_tot=a+b;
```

```
20  V=220;
21  I_m=V/abs(Z_tot);
22  P=6;
23  f=50;
24  n_s=120*f/P;
25  w_s=2*%pi*n_s/60;
26  T_f=(I_m^2*R_2/(2*w_s))*(1/s);
27  T_b=(I_m^2*R_2/(2*w_s))*(1/(2-s));
28  T_tot=T_f-T_b;
29  disp(T_tot,'gross total torque(Nm)');
30  a=T_f/T_tot;
31  b=T_b/T_tot;
32  disp(a,'T_f/T_total');
33  disp(b,'T_b/T_total');
```

Scilab code Exa 10.2 to calculate parameters of the ckt model line current power f

```
1  // to calculate parameters of the ckt model, line
       current, power factor, shaft torque and
       efficiency
2
3  clc;
4  V_0=215;
5  I_0=3.9;
6  P_0=185;
7  R_1=1.6;
8  V_sc=85;
9  I_sc=9.8;
10  P_sc=390;
11  X=(V_0/I_0)*2;              //magnetisation reactance
12  phi_sc=acosd(P_sc/(V_sc*I_sc));
13  I_e=V_sc/complex(0,X);
14  I_SC=I_sc*complex(cosd(phi_sc*(-1)),sind(phi_sc*(-1)
       ));
15  I_m=I_SC-I_e;
```

```
16  Z=V_sc/I_m;
17  R_2=real(Z)-R_1;        //real(Z)=R=R1+R2
18  disp(R_2,'R_2(ohm)');
19  disp(imag(Z),'X_1+X_2(ohm)');
20
21  n=1500;      nn=1440;
22  s=(n-nn)/n;
23  a=1.55/s;
24  b=1.55/(2-s);
25  Z_ftot=(complex(0,X/2))*(complex(a+.8,imag(Z)/2))/((
        complex(0,X/2))+(complex(a+.8,imag(Z)/2)));
26  Z_btot=(complex(0,X/2))*(complex(b+.8,imag(Z)/2))/((
        complex(0,X/2))+(complex(b+.8,imag(Z)/2)));
27  Z_tot=Z_ftot+Z_btot;
28  I_m=V_0/Z_tot;
29  I_L=abs(I_m);disp(I_L,'line current(A)');
30  pf=cosd(atand(real(I_m)/imag(I_m)));     disp(pf,'pf'
        );
31  P_in=V_0*I_L*pf;
32  I_mf=I_m*complex(0,X/2)/complex(39.55,59.12);
33  I_mb=I_m*complex(0,X/2)/complex(1.59,59.12);
34  T=(1/157.1)*(abs(I_mf)^2*38.75-abs(I_mb)^2*.79);
35  P_m=157.1*(1-s)*T;
36  P_L=185;
37  P_out=P_m-P_L;
38  eff=P_out/P_in;     disp(eff*100,'efficiency(%)');
39  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

```
1  //to compute ampitudes of forward and backward
       stator mmf waves,magnitude of auxillary currrent
       and its ph angle diff
2
```

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```
3  clc;
4  N_m=80;
5  N_a=100;
6  I_m=15*complex(cosd(0),sind(0));
7  I_aa=7.5*complex(cosd(45),sind(45));
8  I_a=7.5*complex(cosd(60),sind(60));
9  F_m=N_m*I_m;
10 F_a=N_a*I_a;
11 F_aa=N_a*I_aa;      //mmf at 45 angle
12 F_f=(1/2)*(F_m+imult(F_aa));a=abs(F_f);
13 disp(a,'forward field(AT)');
14 F_b=(1/2)*(F_m-imult(F_aa));b=abs(F_b);
15 disp(b,'backward field(AT)');
16 //1200+100*I_a*complex(sind(a),cosd(a))=0
17 //equating real and imaginery parts
18 //100*I_a*cosd(a)=0;
19 a=90;
20     disp(a,'phase angle diff');
21 I_a=-1200/(100*sind(a));     disp(I_a,'auxillery
      current(A)');
```

Scilab code Exa 10.4 to determine value of capacitor

```
1  //to determine value of capacitor
2
3  clc;
4  f=50;
5  w=2*%pi*f;
6  Z_lm=complex(3,2.7);
7  Z_la=complex(7,3);
8  I_m=(-1)*atand(imag(Z_lm)/imag(Z_la));
9  a=90;
10 I_a=a+I_m;
11 c=1/(w*(real(Z_lm)-real(Z_la)*tand((-1)*I_a)));
12 disp(c,'value of capacitor(F)');
```

```
1  //to calculate starting torque and current ,value of
       run capacitor ,motor performance
2
3  clc;
4  R_lm =4.2;
5  X_lm =11.3;
6  R_la =5.16;
7  X_la =12.1;
8  X =250;
9  a =1.05;
10 R_2 =7.48;
11 X_2 =7.2;
12 Z_f =( complex (0 , X ) * complex ( R_2 , X_2 )) /( complex (0 , X )+
       complex ( R_2 , X_2 ));
13 c =314*70*10^ -6;
14 Z_la = complex ( R_la , X_la -1/ c );
15 Z_lm = complex ( R_lm , X_lm );
16 Z_12 =(1/2) *( Z_la /( a ^2) -( Z_lm ));
17 V =220;
18 V_mf =( V /2) * complex (1 , -1/ a );
19 V_mb =( V /2) * complex (1 ,1/ a );
20 Z = Z_lm + Z_f + Z_12 ;
21 I_mf =( V_mf * Z + V_mb * Z_12 ) /( Z ^2 - Z_12 ^2) ;
22 I_mb =( V_mb * Z + V_mf * Z_12 ) /( Z ^2 - Z_12 ^2) ;
23 n_s =1500;
24 w_s =2* % pi * n_s /60;
25 T_s =(2/ w_s ) * real ( Z_f ) *( abs ( I_mf ) ^2+ abs ( I_mb ) ^2) ; disp
       ( T_s , ' starting  torque (Nm) ');
26 I_m = I_mf + I_mb ;
27 I_a = imult ( I_mf - I_mb )/ a ;
28 I_L = I_m + I_a ;
29 disp ( abs ( I_L ) , 'I_L ( start )(A) ');
```

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```
30
31  s =.04;
32  Z_f =( complex (0 , X )* complex ( R_2 / s , X_2 ))/( complex (0 , X )+
       complex ( R_2 / s , X_2 ));
33  Z_12 =( -1/2)* complex (1 ,1/ a )*( Z_lm + Z_f );
34  Z_1a = a ^2*(2* Z_12 + Z_lm );
35  Z = Z_1a - R_la - imult ( X_la );
36  X_c =( -1)* imag ( Z );
37  C =1/(314* X_c *10^ -6); disp (C , 'value  of  run  capacitor (
       uF ) ');
38
39  Z_f =( complex (0 , X )* complex ( R_2 / s , X_2 ))/( complex (0 , X )+
       complex ( R_2 / s , X_2 ));
40  Z_b =( complex (0 , X )* complex ( R_2 /(2 - s ) , X_2 ))/( complex
       (0 , X )+ complex ( R_2 /(2 - s ) , X_2 ));
41  Z_la = complex ( R_la , X_la ) - imult (10^6/(314* C ));
42  Z_12 =(1/2)*(( Z_la /( a ^2)) - complex ( R_lm , X_lm ));
43  Z1 = Z_lm + Z_f + Z_12 ;
44  Z2 = Z_lm + Z_b + Z_12 ;
45  I_mf =( V_mf * Z2 + V_mb * Z_12 )/( Z1 * Z2 -( Z_12 )^2);
46  I_mb =( V_mb * Z1 + V_mf * Z_12 )/( Z1 * Z2 -( Z_12 )^2);
47  T =(2/157.1)*(( abs ( I_mf )^2* real ( Z_f )) -( abs ( I_mb )^2*
       real ( Z_b )));
48  I_m = I_mf + I_mb ;
49  I_a = imult ( I_mf - I_mb )/ a ;
50  I_L = I_m + I_a ;
51  I_l = abs ( I_L );     pf =1;
52  P_m =2*(( abs ( I_mf )^2* real ( Z_f )) -( abs ( I_mb )^2* real ( Z_b
       ))) *(1 - s );
53  P_L =45;
54  P_out = P_m - P_L ;
55  P_in = I_l * V ;
56  n = P_out / P_in ;
57  disp (n , 'efficiency ');
```

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

```
1  //to calculate starting torque and starting current ,
     motor performance
2
3  clc;
4  clear
5   V = 220;
6  V_a=110*complex(cosd(90),sind(90));
7  V_m=220*complex(cosd(0),sind(0));
8  R_1=3;
9  R_2=2.6;
10  X_1=2.7;
11  X_2=2.7;
12  X=110;
13  V_f=(1/2)*(V_m-imult(V_a));
14  V_b=(1/2)*(V_m+imult(V_a));
15  Z_f=(complex(0,X)*complex(R_2,X_2))/(complex(0,X)+
     complex(R_2,X_2));
16  Z_b=Z_f;
17  Z_ftot=complex(R_1,X_1)+Z_f;
18  Z_btot=complex(R_1,X_1)+Z_b;
19  I_f=V_f/Z_ftot;
20  I_b=V_b/Z_btot;
21  T_s=(2/157)*real(Z_f)*(abs(I_f)^2-abs(I_b)^2);disp(
     T_s,'starting torque(Nm)');
22  I_m=I_f+I_b;
23  I_a=imult(I_f-I_b);disp(abs(I_a),'starting current(A
     )');
24  s=0.04;
25
26  Z_f=(complex(0,X)*complex(R_2/s,X_2))/(complex(0,X)+
     complex(R_2/s,X_2));
27  Z_b=(complex(0,X)*complex(R_2/(2-s),X_2))/(complex
     (0,X)+complex(R_2/(2-s),X_2));
28  Z_ftot=complex(R_1,X_1)+Z_f;
29  Z_btot=complex(R_1,X_1)+Z_b;
30  I_f=V_f/Z_ftot;
```

```
31  I_b=V_b/Z_btot;
32  w_s=157.1;
33  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)');
34  I_m=I_f+I_b;m=atand(imag(I_m)/real(I_m));
35  I_a=imult(I_f-I_b);a=atand(imag(I_a)/real(I_a));
36  P_m=w_s*(1-s)*T_s;
37  P_L=200;
38  P_out=P_m-P_L;
39  P_min=V*abs(I_m)*cosd(m);
40  P_ain=V*abs(I_a)*cosd(a);
41  P_in=P_min+P_ain;
42  n=P_out/P_in;
43  disp(n,'efficiency');
44
45  r=Z_ftot/Z_btot;       //r=V_mf/V_bf
46  //V_mf+V_bf=220
47  V_mf=220/(1+r);
48  V_mb=220-V_mf;
49  V_a=imult(V_mf-V_mb);
50  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

```
1 //calculate power fed to load
2
3 clc;
4 V=100;
5 Va=(V/(sqrt(2)*%pi))*(2+1/sqrt(2));
6 Rd=10;
7 Pa=Va^2/Rd;
8 disp(Pa,'load power(W)');
```

Scilab code Exa 12.2 calculate firing angle value

```
1 //calculate firing angle value
2
3 clc;
4 clear
5  V = 220;
```

```
6  Po =15000;
7  Ro =1.5;
8  Va=sqrt(Po*Ro);
9  a=acosd((Va*2*%pi/(3*sqrt(6)*V))-1);disp(a,'firing
      angle(deg)');
10  Ia=Va/Ro;
11  Ith=Ia/3;disp(Ith,'avg current through diodes(A)');
```

Scilab code Exa 12.3 calculate value of commutating capacitor

```
1  // calculate value of commutating capacitor
2
3  clc;
4  Iamax=100;
5  V=100;
6  f_max=400;
7  c=Iamax/(2*V*f_max);
8  disp(c,'value of commutating capacitor(F)');
```