Scilab Textbook Companion for Electrical Machines by R. K. Srivastava[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 2

Forces in a Electromagnetic System

Scilab code Exa 2.1 To find flux flux density and magnetic field intensity in the core

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 2 : FORCES IN AN ELECTROMAGNETIC
       SYSTEMS
8
9  // EXAMPLE : 2.1
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 A = 0.0001;              // The Cross−sectional
```

```
         area of core in metre−square
17  Mo = 4*%pi*(10)^(-7);          // Permeability of air in
         Henre/metre
18  Mr = 1000;                     // Relative permeability
         of core
19  N1 = 10;N2=20;N3=10;           // Number of turns
20  I1 = 1.0;I2=0.5;I3=1.5;        // Currents in Amphere
21  d = 2.5;                       // Dimension of inner
         window in centimetre
22  w = 1.0;                       // Each limb wide in
         centimeter
23
24
25  // CALCULATIONS
26
27  F = (N1*I1)+(N2*I2)-(N3*I3);            // MMF in
         Amphere−turns ( minus because third coil produces
         the flux in opposite direction to that of other
         to coils )
28  L = ((d*4)+(I2*2*4))*10^-2;            // Length of
         the Magnetic path in metre (4−is sides of the
         windows )(2−Going and returning of current I2)
29  R = L/(Mr*Mo*A);                       // Reluctance
         of the Magnetic path in MKS unit of Reluctance
30  phi = (F*10^3)/R;                      // Flux in
         milli−Weber
31  B = phi/A;                             // Flux
         Density in Weber/metre Square
32  H = F/L;                               // Magnetic
         Field Intensity in Amphere−turns/Metre
33
34
35  // DISPLAY RESULTS
36
37  disp("EXAMPLE : 2.1 : SOLUTION :−") ;
38  printf("\n (a) Flux in the core, phi = %.6f mWb ,\n"
         ,phi);
39  printf("\n (b) Flux Density in the core, B = %.2f Wb
```

```
      /metre square   \n",B);
40 printf("\n (c) Magnetic Field Intensity in the core,
      H = %.2f At/m   \n",H);
```

Scilab code Exa 2.2 To find Total MMF coil current relative permeability of each ferromagnetic material and inductance of the coil

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 2 : FORCES IN AN ELECTROMAGNETIC
      SYSTEMS
8
9  // EXAMPLE : 2.2
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 N = 100;                    // Number of turns
17 La = 0.3;                   // Mean arc length of
      material "a" is a Nickel-iron alloy in Metre
18 Lb = 0.2;                   // Mean arc length of
      material "b" is a Steel in Metre
19 Lc = 0.1;                   // Mean arc length of
      material "c" is a Cast Steel in Metre
20 a = 0.001;                  // Area of the all Materials
      "a,b,c" in Metre-Square
21 phi = 6*10^-4;              // Magnetic Flux in Weber
22 mue_0 = 4*%pi*10^ -7;   // Permeability of the air in
```

```
        Henry/Meter
23
24
25  // CALCULATIONS
26
27  B = phi/a;                              // Flux Density in
        Telsa (Here Flux Density same for all the
        Materials "a,b,c" because Area of Cross Section
        is Same)
28  Ha = 10;                                // Fileld Intensity
        in Amphere-Turn/Meter Correspounding to Flux
        density (B) of material "a" obtained from the
        Standard B-H curve
29  Hb = 77;                                // Fileld Intensity
        in Amphere-Turn/Meter Correspounding to Flux
        density (B) of material "b" obtained from the
        Standard B-H curve
30  Hc = 270;                               // Fileld Intensity
        in Amphere-Turn/Meter Correspounding to Flux
        density (B) of material "c" obtained from the
        Standard B-H curve
31  F = (Ha*La)+(Hb*Lb)+(Hc*Lc);    // The Total MMF
        Required in Amphere-Turns
32  I = F/N;                                // Current flowing
        through the Coil in Amphere
33  mue_r_a = B/(Ha*mue_0);         // Relatative
        permeability of the Material "a"
34  mue_r_b = B/(Hb*mue_0);         // Relatative
        permeability of the Material "a"
35  mue_r_c = B/(Hc*mue_0);         // Relatative
        permeability of the Material "a"
36  Ra = (Ha*La)/phi;                       // Relucatnce of the
        Material "a" in MKS unit
37  Rb = (Hb*Lb)/phi;                       // Relucatnce of the
        Material "b" in MKS unit
38  Rc = (Hc*Lc)/phi;                       // Relucatnce of the
        Material "c" in MKS unit
39  L = (N*phi)/I;                          // Inductance of the
```

14

```
     Coil  in  Henry
40
41
42 // DISPLAY RESULTS
43
44 disp("EXAMPLE : 2.2 : SOLUTION :−") ;
45 printf("\n (a)   The Total MMF , F = %.1f At \n ",F)
      ;
46 printf("\n (b)   Current flowing through the Coil ,
      I = %.3f A \n",I);
47 printf("\n (c.1) Relatative permeability of the
      Material a, mue_r_a = %.f \n ",mue_r_a);
48 printf("\n (c.2) Relatative permeability of the
      Material b, mue_r_b = %.f \n ",mue_r_b);
49 printf("\n (c.3) Relatative permeability of the
      Material c, mue_r_c = %.f \n ",mue_r_c);
50 printf("\n (c.4) Relucatnce of the Material a, Ra= %
      .f MKS unit \n",Ra);
51 printf("\n (c.5) Relucatnce of the Material b, Rb= %
      .1f MKS unit \n",Rb);
52 printf("\n (c.6) Relucatnce of the Material c, Rc= %
      .f MKS unit \n",Rc);
53 printf("\n (d)   Inductance of the Coil , L = %.4f H
      \n",L);
```

Scilab code Exa 2.3 To find magnetic field produced by an appiled MMf of 35At

```
1
2 // ELECTRICAL MACHINES
3 // R.K.Srivartava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 2 : FORCES IN AN ELECTROMAGNETIC
```

```scilab
8
9  // EXAMPLE : 2.3
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 F = 35;                    // Total MMF in Amphere−Turns
17 Lc = 0.1;                  // Inductance of The Material
       "c" in Henry
18 a = 0.001;                 // Area of the all Materials
       "a,b,c" in Metre−Square
19
20
21 // CALCULATIONS
22
23 Hc = F/Lc;                 // Field Intensity in
       Amphere−Turns/Meter (Given that entire MMf
       apperas on Material "c" Because of the highest
       reluctance about 45000 MKS unit From Example 2.2)
24 Bc = 0.65;                 // Flux density of material
       "c" in in Telsa obtained from the Standard B−H
       curve
25 phi = Bc*a;                // Flux in the core in Weber
26 Ba = Bc;                   // Flux density of material
       "a" in in Telsa Same because Area of Cross
       Section is Same
27 Bb = Bc;                   // Flux density of material
       "b" in in Telsabecause Area of Cross Section is
       Same
28
29
30 // DISPLAY RESULTS
31
32 disp("EXAMPLE : 2.3 : SOLUTION :−") ;
```

```
33  printf("\n (a) Flux in the core , phi = %.5f Wb \n "
       ,phi);
34  printf("\n (b) Flux density of material a,b,c , Ba =
       Bb = Bc %.2f T \n",Ba);
```

Scilab code Exa 2.4 To find flux density in air gap output of the sensor
if hall effect generates voltage of 50 millivolt per 1 telsa and ratio of flux
density without and with air gap

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 2 : FORCES IN AN ELECTROMAGNETIC
       SYSTEMS
8
9  // EXAMPLE : 2.4
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15 // Refer figure 2.7:- Page no. 41
16
17 a = 0.0001;                    // Cross Sectional Area
       of the Core in Meter-Square
18 Li = 0.158;                    // Total length of the
       Path abcdef in Meter (4.0*4.0 - 0.2 = 15.8cm =
       0.158m)
19 Lg = 0.002;                    // Length of the air gap
       in Meter
20 mue_0 = 4*%pi*10^-7;          // Permeability of the
```

```
                 air  in  Henry/Meter
21  mue_r = 10000;                     //  Permeability  of  the
         core
22  N = 10;                            //  Number  of  Turns
23  I = 1.0;                           //  Current  in  the  Coil  in
         Amphere
24  v = 50;                            //  hall  effect  sensor
         generates  volatge  produces  in  milli  volt  per  1
         Telsa
25  Li_new = 0.16;                     //  Length  of  the  Flux
         path  in  Absence  of  the  Air  gap  in  Meter
26
27
28  // CALCUALTIONS
29
30  F = N*I;                           //  MMF  of  the  Coil
         in  Amphere-turn
31  Ri = Li/(mue_0*mue_r*a);           //  Relucatnce  of
         the  Iron  Coil  in  MKS  unit
32  Rg = Lg/(mue_0*a);                 //  Relucatnce  of
         air  gap  in  MKS  unit
33  R = Ri+Rg;                         //  Total  Reluctance
          in  MKS  unit
34  phi = F/R;                         //  Flux  in  the  Core
          in  Weber
35  B = phi/a;                         //  FLux  density  in
         the  core(Presence  of  the  Air  gap)  in  Weber/Meter-
         Square
36  HEV = B*50;                        //  Output  of  the
         Hall  effect  Sensor  device  in  Milli-Volt
37  R_new = Li_new/(mue_0*mue_r*a)     //  Relucatance  of
         the  Magnetic  Circuit  in  Absence  of  the  Air  gap
38  phi_new = F/R_new;                 //  New  Flux  in  the
         Core  in  Weber
39  B_new = phi_new/a;                 //  New  FLux  density
          in  the  core  in  Weber/Meter-Square
40  Ratio = B_new/B;                   //  Ratio  of  the
         Flux  Density  in  Absence  of  the  Air  gap  and  in  the
```

```
        presence  of  the  Air  gap
41
42
43  // DISPLAY RESULTS
44
45  disp("EXAMPLE  :  2.4  :  SOLUTION :−") ;
46  printf("\n (a) Flux density in the core (Presence of
         the Air gap) , B = %.8 f Wb/Meter−Square \n ",B);
47  printf("\n (b) Output of the Hall effect Sensor
         device , HEV = %.7 f mV \n",HEV);
48  printf("\n (c) Ratio of the Flux Density in Absence
         of the Air gap and in the presence of the Air gap
          , Ratio = %.2 f \n ",Ratio);
```

Scilab code Exa 2.5 To find how many turns should the exciting coil have in order to establish a flux density of 1 Wb per meter square if core made up of silicon steel having 1 telsa and 200 At per meter and ferrite core having relative permeability of 20000

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  //  First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 2 : FORCES IN AN ELECTROMAGNETIC
      SYSTEMS
8
9  // EXAMPLE : 2.5
10
11  clear ; clc ; close ; // Clear the work space and
       console
12
13
14  // GIVEN DATA
```

```scilab
15  // Refer figure 2.3(a):- Page no. 36
16
17  B = 1.0;                            // Flux Density in the
        Core in Weber/Meter-Square
18  Liron = 0.55;                       // Mean length of the
        flux path of Iron in Meter
19  Lair = 0.002;                       // Mean length of the
        flux path of Air Gap in Meter
20  I = 20;                             // Coil Current in
        Amphere
21  H = 200;                            // Field Intensity in
        Amphere-Turns/Meter
22  mue_r = 20000;                      // Relative permeability
          of Ferrite core
23  mue_0 = 4*%pi*10^-7;                // Permeability of the
        air in Henry/Meter
24  a = 0.0025;                         // Area of the Cross
        sectional of the core oin Metre-Square
25
26
27  // CALCULATIONS
28
29  phi = B*a;                                  // Toatl Flux
          in the core in Weber
30  Rair = Lair/(mue_0*a);                      // Relucatnce
          in the Air gap
31  Fair = Rair*phi;                            // MMf in the
          Air gap in Amphere-Turns
32  Firon = H*Liron;                            // MMf in the
          Iron core in Amphere-Turns
33  F = Firon+Fair;                             // Total MMF
        in Amphere-Turns
34  N = F/I;                                    // Number of
        turns in the Coil
35  F_new = B/(mue_0*mue_r);                    // Field
        Intensity in Amphere-Turns/Meter
36  F_new_total = (Fair+F_new);                 // Total MMF
        in Amphere-Turns
```

```
37  N_new = F_new_total/I;                          // Number of
        turns  in  the  Coil
38
39
40  // DISPLAY RESULTS
41
42  disp("EXAMPLE : 2.5 : SOLUTION :−") ;
43  printf("\n (a) Number of turns in the Coil in air
        gap made of Silicon Steel having an field
        intensity 200At/m corresounds to 1.0 T Flux
        Density , N = %.2f appoximately 85 \n ",N);
44  printf("\n (b) Number of turns in the Coil for a
        ferrite core of having Relative premeability of
        20000 and magnetic Field Density corresponnds to
        1.0 T , N_new = %.2f appoximately 82   \n",N_new);
```

Chapter 3

Transformers

Scilab code Exa 3.1 To find voltage drops line losses and generating voltage

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.1
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 Z = (0.05 + 0.05 * %i) * 100;          //
       Transmission line parameters (impedance) in Ohms
       (multiplied by 100 because distance of the
       Transmission line is 100km)
```

```
17  R = 0.05 * 100;                          //
        Transmission line Resistance in Ohms (multiplied
        by 100 because distance of the Transmission line
        is 100km)
18  V1 = 220;                                    // Terminal
        voltage in Volts
19  V2 = 1 * 10 ^ 3;                             // Terminal
        volatge from Generator side in Volts
20  P = 20 * 10 ^ 3;                             // Power in
        Watts
21
22
23  // CACULATIONS
24
25  I1 = P/V1;                               // Line current
        for 220V in Amphere
26  I2 = P/V2;                               // Line current
        for 1kV in Amphere
27  I1Z = Z*I1;                              // Voltage drop
        due to I1 in Volts
28  I2Z = Z*I2;                              // Voltage drop
        due to I2 in Volts
29  Loss1 = (I1 ^ 2) * R * 10 ^ -3;         // Line loss for
         I1 in kW
30  Loss2 = (I2 ^ 2) * R * 10 ^ -3;         // Line loss for
         I2 in kW
31  Vg1 = V1 + I1Z;                          // Input
        Voltages on Generator Terminal in Volts
32  Vg2 = V2 + I2Z;                          // Input
        Voltages on Generator Terminal in Volts
33
34
35  // DISPLAY RESULTS
36
37  disp("EXAMPLE : 3.1 : SOLUTION :-") ;
38  printf("\n (a.1) Voltage drop due to I1 , I1Z = % .2
        f+j%.2f   V \n ",real(I1Z),imag(I1Z));
39  printf("\n (a.2) Voltage drop due to I2 , I2Z = % .f
```

```
                   +j%.f  V \n",real(I2Z),imag(I2Z));
40  printf("\n (b.1) Line loss for I1 , Loss1 = %.2f kW
        \n ",Loss1);
41  printf("\n (b.2) Line loss for I2 , Loss2 = % .2f kW
         \n",Loss2);
42  printf("\n (c.1) Input Voltages on Generator
        Terminal from a load terminal , Vg1 = %.2f+j%.2f
        = %.2f V \n ",real(Vg1),imag(Vg1),abs(Vg1));
43  printf("\n (c.2) Input Voltages on Generator
        Terminal from a Generating Station , Vg2 = % .f+
        j%.f = %.2f V \n",real(Vg2),imag(Vg2),abs(Vg2));
44  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
45  printf("\n        WRONGLY PRINTED ANSWERS ARE :− (a)
        I1Z = (450.45)+j(450.45)V instead of (454.55)+j
        (454.55) V\n" );
46  printf("\n                                        (b)
        Vg1 = (670.45)+j(450.45) = 807.72 V  instead of %
         .2f+j%.2f = %.2f V \n",real(Vg1),imag(Vg1),abs(
        Vg1) );
```

Scilab code Exa 3.2 To find numbers of turns in each winding and voltage per turn

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.2
10
```

```
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  E1 = 6.6 * 10 ^ 3;                  // Primary voltage
        in Volts
17  E2 = 220;                           // Secondary Voltage
         in volts
18  f = 50;                             // Frequency in
        Hertz
19  phi_m = 0.06;                       // Flux in Weber
20  S = 50 * 10^6;                      // Rating of the
        single-phase transformer in VA
21
22  // CALCULATIONS
23
24  N1 = E1/(4.44*f*phi_m);             // Number of turns
        in Primary
25  vpn1 = E1/N1;                       // Voltage per
        turns in Primary in Volts/turn
26  N2 = E2/(4.44*f*phi_m);             // Number of turns
        in Secondary
27  vpn2 = E2/N2;                       // Voltage per
        turns in Secondary in Volts/turn
28
29
30  // DISPLAY RESULTS
31
32  disp("EXAMPLE : 3.2 : SOLUTION :-") ;
33  printf("\n (a.1) Number of turns in Primary , N1 = %
        .1f Turns nearly 496 Turns \n ",N1);
34  printf("\n (a.2) Number of turns in Secondary , N2 =
        %.1f Turns nearly 16 Turns \n",N2);
35  printf("\n (b.1) Voltage per turns in Primary , vpn1
        = %.1f Volts/turns \n ",vpn1);
36  printf("\n (b.2) Voltage per turns in Secondary ,
```

```
        vpn2 = %.2 f  Volts / turns  \n ", vpn2 ) ;
```

Scilab code Exa 3.3 To find maximum value of the core flux

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.3
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 f = 50;                    // Frequency in Hertz
17 N = 50;                    // Number of turns in
       Secondary
18 E =220;                    // Induced voltage in Volts
19
20
21 // CALCULATIONs
22
23 phi_m = E/(4.44*f*N);         // Maximum value of the
        Flux in Weber
24
25
26 // DISPLAY RESULTS
27
28 disp("EXAMPLE : 3.3 : SOLUTION :-") ;
```

```
29  printf("\n (a) Maximum value of the Flux , phi_m = %
        .7 f Wb \n ",phi_m);
```

Scilab code Exa 3.4 To find rated currents of the two windings

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.4
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 S = 1.5;                     // Transformer Rating in KVA
17 E1 = 220;                    // HV side voltage in volts
18 E2 = 40;                     // LV side voltage in volts
19
20
21 // CALCULATION
22
23 Ihv = (S * 10 ^ 3)/E1;              // Rated HV side
       Curent in Amphere
24 Ilv = (S * 10 ^ 3)/E2;              // Rated lV side
       Curent in Amphere
25
26
27 // DISPLAY RESULTS
```

```
28
29  disp ("EXAMPLE :  3.4  : SOLUTION :−") ;
30  printf ("\n (a) Rated HV side Curent , Ihv = %.2 f A \
       n " ,Ihv);
31  printf ("\n (b) Rated LV side Curent , Ilv = %.1 f A \
       n" ,Ilv);
```

Scilab code Exa 3.5 To find maximum flux no load current no load power factor of the transformer

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.5
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 Ai = 2.3 * 10 ^ -3;                    // Cross−
       Sectional area of the core in Meter−Square
17 mue_0 = 4*%pi*10^ -7;                  // Permeability
       of the air in Henry/Meter
18 Fe_loss = 2.6;                         // Iron loss at
       the working Flux density Watts/kg
19 Fe_den = 7.8 * 10 ^ 3;                 // Density of
       the Iron in kg/Meter−Cube
20 N1 = 800;                              // Number of
```

```scilab
                Turns  of  the  Primary  winding
21  L = 2.5;                                    // Length  of  the
                Flux  path  in  Meter
22  mue_r = 1000;                               // Relative
                Permeability
23  E = 400;                                    // Primary
                Volatge  of  the  Transformer  in  Volts
24  f = 50;                                     // Frequency  in
                Hertz
25
26
27  // CALCULATIONS
28
29  Bm = E/(4.44*f*Ai*800);                     // Flux  Density
                in  Weber/Meter-Square
30  phi_m = (Bm*Ai)*10^3;                       // Maximum  Flux
                in  the  core  in  milli-Weber
31  F = (L*Bm)/(mue_r*mue_0);                   // Magnetizing
                MMF  in  Amphere-turns
32  Im = F/(N1*sqrt(2));                        // Magnetizing
                Current  in  Amphere
33  Vol = L*Ai;                                 // Volume  of  the
                Core  in  Meter-Cube
34  W = Vol * Fe_den;                           // Weight  of  the
                Core  in  kg
35  Total_Fe_loss = Fe_loss * W;                // Total  Iron
                loss  in  Watt
36  Ic = Total_Fe_loss/E;                       // Loss
                component  of  Current  in  Amphere
37  Io= sqrt((Ic ^ 2)+(Im ^ 2));               // No load
                Current  in  Amphere
38  pf_angle = atand(Io/Ic);                    // No load  Power
                factor  angle  in  degree
39  pf = cosd(pf_angle);                        // No load  Power
                factor
40
41
42  // DISPLAY  RESULTS
```

```
43
44  disp("EXAMPLE :  3.5  : SOLUTION :-") ;
45  printf("\n (a) Maximum Flux in the core , phi_m = %
        .6 f mWb \n ",phi_m);
46  printf("\n (b) No load Current , I0 = %.3 f A \n",Io)
        ;
47  printf("\n (c) No load Power factor angle  = %.3 f
        degree \n ",pf_angle);
48  printf("\n (d) No load Power factor = %.4 f \n ",pf)
        ;
```

Scilab code Exa 3.6 To find turn ratio primary and secondary currents at full load and at 4kW load at pf lagging 80 percent

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.6
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  S = 5;                    // Transformer Rating in kVA
17  V1 = 220;                 // HV side voltage in volts
18  V2 = 110;                 // LV side voltage in Volts
19  P = 4 * 10 ^ 2;           // Load of the Transformer
20  pf = 0.8;                 // Power Factor (lagging)
```

```
21  f = 50;                          // Frequency in Hertz
22
23
24  // CALCULATIONS
25
26  a = V1/V2;                       // Turn Ratio of the
        Transformer
27
28  // case (a) At full load
29  I1 = (S * 10 ^ 3)/V1;           // Primary current at
        full load in Amphere
30  I2 = (S * 10 ^ 3)/V2;           // Secondary Current at
        full Load in Amphere
31
32  // Case (b) At 4kW, 0.8 lagging pf load
33  I11 = (4 * 10 ^ 3 * 0.8)/V1;    // Primary
        current At 4kW, 0.8 lagging pf load in Amphere
34  I22 = (4 * 10 ^ 3 * 0.8)/V2;    // Secondary
        Current At 4kW, 0.8 lagging pf load in Amphere
35
36
37  // DISPLAY RESULTS
38
39  disp("EXAMPLE : 3.6 : SOLUTION :-") ;
40  printf("\n    (a)   Turn Ratio of the Transformer , a
        = %.f \n ",a);
41  printf("\n (b.1.1) Primary current at full load , I1
        = %.2f A \n",I1);
42  printf("\n (b.1.2) Secondary current at full load ,
        I2 = %.2f A \n ",I2);
43  printf("\n (b.2.1) Primary current at 4kW, 0.8
        lagging pf load , I1 = %.3f A \n",I11);
44  printf("\n (b.2.1) Secondary current at 4kW, 0.8
        lagging pf load , I2 = %.3f A \n",I22);
```

Scilab code Exa 3.7 To find referred value of resistance from primary side

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.7
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 a = 100/200;                          // Turn ratio of
        the Ideal transformer
17 R = 1.0;                              // Resistance
       across the secondary side having 200 turns in
       Ohms
18
19
20 // CALCULATIONS
21
22 R1 = (a ^ 2)*R;                       // Referred
       value of the resistance from Primary side having
       100 turns in Ohms
23
24
25 // DISPLAY RESULTS
26
27 disp("EXAMPLE : 3.7 : SOLUTION :-") ;
28 printf("\n (a) Referred value of the %.f Ohm
       resistance from Primary side having 100 turns ,
       R1 = %.2 f ohms \n ",R,R1);
```

```
29  printf("\n\n      [ TEXT BOOK SOLUTION  IS  PRINTED
        WRONGLY ( I  verified  by  manual  calculation  )]\n"
        );
30  printf("\n          WRONGLY PRINTED ANSWERS ARE :− (a)
        Referred  value  of  the  resistance  from  Primary
        side  having  100  turns  =  0.025  Ohms  instead  of  %.2
        f  Ohms  \n ",R1);
```

Scilab code Exa 3.8 To find equivalent resistance as referred to primary and secondary side and full load copper loss

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  3  :  TRANSFORMERS
8
9  // EXAMPLE  :  3.8
10
11  clear ; clc ; close ; // Clear  the  work  space  and
        console
12
13
14  // GIVEN DATA
15
16  S = 60;                    // Tranformer  Rating  in  kVA
17  V1 = 6600;                 // HV Side  Voltage  Rating  of
        the  Transformer  in  Volts
18  V2 = 220;                  // LV Side  Voltage  Rating  of
        the  Transformer  in  Volts
19  R1 = 7.8;                  // primary  Resistances  of  the
         Transformer  in  Ohms
20  R2 = 0.0085;               // Secondary  Resistances  of
```

33

```
      the  Transformer  in  Ohms
21
22
23 // CALCULATIONS
24
25 a = V1/V2;                  // Transformation Ratio
26 Rp = R1+(a^2)*R2;        // Resistance referred to
      Primary side in Ohms
27 Rs = (R1/(a^2))+R2;      // Resistance referred to
      Secondary side in Ohms
28 Ip = (S*1000)/V1         //  Current in Primary Side
      in Ampheres
29 Cu_loss = Rp*(Ip^2);    // Copper loss in Transformer
       in Watts
30
31
32 // DISPLAY RESULTS
33
34 disp("EXAMPLE : 3.8 : SOLUTION :−") ;
35 printf("\n (a) Equlivalent Resistance as Referred to
        Primary Side , Rp = % .2 f ohms \n",Rp)
36 printf("\n (b) Equlivalent Resistance as Referred to
        Secondary Side , Rs = % .5 f ohms \n",Rs)
37 printf("\n (c) Total Copper Loss , Cu_loss = % .2 f W
      \n",Cu_loss)
```

Scilab code Exa 3.9 To find equivalent resistance referred from primary side

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
```

```
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.9
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 V1 = 11000;              // HV Side Voltage Rating of
      the Transformer in Volts
17 V2 = 440;               // LV Side Voltage Rating of
      the Transformer in Volts
18 R = 1.0;                // Resistance across the
      secondary side having 11kV in Ohms
19
20
21 // CALCULATIONS
22
23 a = V1/V2;                          // Turns ratio
      of the ideal transformers
24 R2 = (a ^ 2)*R;                     // Referred
      value of the resistance from Primary side having
      440V in Ohms
25
26
27 // DISPLAY RESULTS
28
29 disp("EXAMPLE : 3.9 : SOLUTION :-") ;
30 printf("\n (a) Referred value of the resistance from
       Primary side having 440V , R2 = %.f Ohms \n ",R2
      );
```

Scilab code Exa 3.10 To find current taken by primary side

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.10
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 V1 = 440;                                          //
       HV Side Voltage Rating of the Transformer in
       Volts
17 V2 = 220;                                          //
       LV Side Voltage Rating of the Transformer in
       Volts
18 pf_o = 0.2;                                        //
       No-load Power factor lagging
19 pf_l = 0.8;                                        //
       Load Power factor lagging
20 I_o = 5;                                           //
       No-load current in Amphere
21 I_2 = 120;                                         //
       Load current in Amphere
22
23 // CALCULATIONS
24
25 a = V1/V2;                                         //
       Turns ratio of the two winding Transformers
26 theta_o = acosd(pf_o);                             //
       No load power factor of the two winding
       Transformers in Degrees
```

```
27  Io = I_o * exp(-(%i*theta_o*%pi/180));          //
        No load current of the two winding Transformers (
        minus because lagging) in Amphere
28  theta = acosd(pf_l);                            //
        load power factor of the two winding Transformers
         in Degrees
29  I2 = I_2 * exp(-(%i*theta*%pi/180));            //
        secondary load current of the two winding
        Transformers (minus because lagging) in Amphere
30  I21 = I2/a;                                      //
        Secondary referred to the primaryin Amphere
31  I1 = Io + I21;                                   //
        Primary current in Amphere
32  I1_mag = abs(I1);                                //
        Primary current magnitude inj Amphere
33  theta_1 = atand( imag(I1),real(I1));            //
        Primary current angle in Degree
34
35
36  // DISPLAY RESULTS
37
38  disp("EXAMPLE : 3.10 : SOLUTION :-") ;
39  printf("\n (a) Primary current , I1 = %.2f < %.1f A
        \n ",I1_mag,theta_1);
```

Scilab code Exa 3.11 To find core loss no load pf angle pf current through core loss component and core loss resistance current through Xm percentage of exciting current

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
```

```
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.11
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 S = 50;                  // kVA Rating of the Transformer
17 f = 50;                  // Frequency in Hertz
18 Wo = 190;                // Meter Readings when HV
      Winding kept open in Watt
19 Vo = 230;                // Meter Readings when HV
      Winding kept open in Volts
20 Io = 6.5;                // Meter Readings when HV
      Winding kept open in Amphere
21 R2 = 0.06;               // Resistance of the LV Winding
      in Ohms
22 V1 = 2300;               // Voltage across the HV Side in
       Volts
23 V2 = 230;                // Voltage across the LV Side in
       Volts
24 AC = 230;                // Tranformer connected to AC
      mains in Volts
25
26
27 // CALCULATIONS
28
29 a = V1/V2;                                        //
      Trasformation ratio of the Transformer
30 Wc = Wo - ((Io ^ 2) * R2);                        //
      Core loss in Watts
31 Po = Wc;                                          //
      Core loss in Watts
32 Pc = Wc;                                          //
      Core loss in Watts
```

```
33  cos_theta_o = Po/(Vo*Io);                          // No
        load  power  factor
34  theta_o = acosd(cos_theta_o);                      // No
        load  power  factor  angle  in  Degrees
35  Ic = Io * cosd(theta_o);
36  E = V1 - Io * exp(%i*(theta_o)*%pi/180);
37  Rc = Pc/(Ic ^ 2 );                                 //
        Core  loss  Resistance  in  Ohms
38  Im = Io * sind(theta_o);                           //
        Current  through  the  Magnetizing  branch  in  Amphre
39  Xm = E/Im;                                         //
        Magnetizing   Reactance  in  Ohms
40  Ift = (S * 10 ^ 3)/V2;                             //
        Full  Load  current  in  Amphere
41  Ie = (Io/Ift)*100;                                 //
        Percentage  of  the  Exicting  Current  in  Amphere
42
43
44  // DISPLAY RESULTS
45
46  disp("EXAMPLE : 3.11 : SOLUTION :-") ;
47  printf("\n  (a)  Core  loss , Wc = %.2 f W \n ",Wc);
48  printf("\n (b.1) No load power factor angle ,
        theta_o = % .2 f Degree \n",theta_o);
49  printf("\n (b.2) No load power factor , cos(theta_o)
        = % .6 f \n",cos_theta_o );
50  printf("\n (c.1) Curent through Core loss Component
        , Ic = %.4 f A \n ",Ic);
51  printf("\n (c.2) Core  loss  Resistance , Rc = %.2 f
        Ohms \n ",Rc);
52  printf("\n  (d)  Current  through  the  Magnetizing
        Component Xm , Im = % .2 f A \n",Im);
53  printf("\n  (e)  Percentage  of  the  Exicting  Current
        = % .2 f Percent \n",Ie);
```

Scilab code Exa 3.12 To find hysteresis and eddy current losses st 50Hz

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.12
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 N1 = 1000;                  // 1st Test at No-load
       condition f1 Frequency, Speed in RPM
17 Vo1 = 250;                  // 1st Test at No-load
       condition f1 Frequency, Voltage in Volts
18 Io1 = 0.5;                  // 1st Test at No-load
       condition f1 Frequency, Current in Amphere
19 Wo1= 230;                   // 1st Test at No-load
       condition f1 Frequency, Power in Watts
20
21 N2 = 900;                   // 2nd Test at No-load
       condition f2 Frequency, Speed in RPM
22 Vo2 = 225;                  // 2nd Test at No-load
       condition f2 Frequency, Voltage in Volts
23 Io2= 0.5;                   // 2nd Test at No-load
       condition f2 Frequency, Current in Amphere
24 Wo2 = 200;                  // 2nd Test at No-load
       condition f2 Frequency, Power in Watts
25 p = 6;                      // Number of poles of single
        phase alternator
26 N = 220;                    // Number of the turns of
```

```scilab
                single phase alternator
27  R = 0.66;                    // Resistance of the single
        phase alternator in Ohms
28
29
30  // CALCULATIONS
31
32  f1 = (N1*p)/120;                    // 1st case Supply
        Frequency in Hertz
33  Ratio1 = Vo1/f1;                    // 1st case Ratio of
        the Volatge and Frequency in Volts/Hertz
34  f2 = (N2*p)/120;                    // 2nd case Supply
        Frequency in Hertz
35  Ratio2 = Vo2/f2;                    // 2nd case Ratio of
        the Volatge and Frequency in Volts/Hertz
36
37  c = (Wo1-(Io1^2)*R)/f1;         // No-load corrected
            losses Eq 1 in Watts
38  d = (Wo2-(Io2^2)*R)/f2;         // No-load corrected
        losses Eq 2 in watts
39
40  x = [ 1 f1 ; 1 f2 ];            // No-load corrected
            losses Eq 1 in watts
41  y = [ c ; d ];                  // No-load corrected
        losses Eq 2 in watts
42
43  E = x\y;                            // Solution of
        constants A in Watts/Hertz and B in watts/Hertz-
        Sqare in matrix form
44  A = E(1,1);                         // Solution of
        constant A in Watts/Hertz
45  B = E(2,1);                         // Solution of
        constant B in watts/Hertz-Sqare
46  Ph = f1*A;                          // Hysteresis loss
        at 50 Hertz in Watts
47  Pe = (f1^2)*B;                      // Eddy current loss
        at 50 Hertz in Watts
48
```

```
49
50 // DISPLAY RESULTS
51
52 disp("EXAMPLE : 3.12 : SOLUTION :−") ;
53 printf("\n (a) Hysteresis loss at %.f Hertz , Ph = %
    .3f W \n ",f1,Ph);
54 printf("\n (b) Eddy current loss at %.f Hertz , Pe =
    % .2f W \n",f1,Pe);
```

Scilab code Exa 3.13 To find hysteresis and eddy currents

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 3 : TRANSFORMERS
8
9 // EXAMPLE : 3.13
10
11 clear ; clc ; close ; // Clear the work space and
    console
12
13
14 // GIVEN DATA
15
16 N1 = 1500;                    // 1st Test on Transformer
    at f1 Frequency and Vo1 voltage , Speed in RPM
17 Vo1 = 250;                    // 1st Test on Transformer
    at f1 Frequency and Vo1 voltage , Voltage in Volts
18 Wo1= 55;                      // 1st Test on Transformer
    at f1 Frequency and Vo1 voltage , Power in Watts
19 N2 = 1200;                    // 2nd Test on Transformer
    at f2 Frequency and Vo2 voltage , Speed in RPM
```

```
20  Vo2 = 200;                     // 2nd Test on Transformer
        at f2 Frequency and Vo2 voltage, Voltage in Volts
21  Wo2 = 40;                      // 2nd Test on Transformer
        at f2 Frequency and Vo2 voltage, Power in Watts
22  p = 4;                         // Number of poles of
        single phase alternator
23
24
25  // CALCULATIONS
26
27  f1 = (N1*p)/120;                    // 1st case Supply
        Frequency in Hertz
28  Ratio1 = Vo1/f1;                    // 1st case Ratio of
        the Volatge and Frequency in Volts/Hertz
29  f2 = (N2*p)/120;                    // 2nd case Supply
        Frequency in Hertz
30  Ratio2 = Vo2/f2;                    // 2nd case Ratio of
        the Volatge and Frequency in Volts/Hertz
31
32  c = Wo1/f1;           // No-load corrected losses Eq 1
         in Watts
33  d = Wo2/f2;           // No-load corrected losses Eq 2
         in watts
34
35  x = [ 1 f1 ; 1 f2 ];                // No-load
        corrected losses Eq 1 in watts
36  y = [ c ; d ];                      // No-load
        corrected losses Eq 2 in watts
37
38  E = x\y;                            // Solution of
        constants A in Watts/Hertz and B in watts/Hertz-
        Sqare in matrix form
39  A = E(1,1);                         // Solution of
        constant A in Watts/Hertz
40  B = E(2,1);                         // Solution of
        constant B in watts/Hertz-Sqare
41  Ph1 = f1*A;                         // Hysteresis loss
        at 50 Hertz in Watts
```

```
42  Pe1 = (f1^2)*B;                          // Eddy  current
       loss  at  50  Hertz  in  Watts
43  Ph2 = f2*A;                              // Hysteresis  loss
       at  40  Hertz  in  Watts
44  Pe2 = (f2^2)*B;                          // Eddy  current
       loss  at  40  Hertz  in  Watts
45
46
47  // DISPLAY RESULTS
48
49  disp("EXAMPLE : 3.13 : SOLUTION :−") ;
50  printf("\n (a.1) Hysteresis loss at %.f Hertz , Ph =
       %.f W \n ",f1,Ph1);
51  printf("\n (a.2) Eddy current loss at %.f Hertz , Pe
       = %.f W \n",f1,Pe1);
52  printf("\n (b.1) Hysteresis loss at %.f Hertz , Ph =
       %.f W \n ",f2,Ph2);
53  printf("\n (b.2) Eddy current loss at %.f Hertz , Pe
       = %.f W \n",f2,Pe2);
54  printf("\n\n      [ TEXT BOOK SOLUTION IS PRINTED
       WRONGLY ( I verified by manual calculation )]\n"
       );
55  printf("\n        WRONGLY PRINTED ANSWERS ARE :− (a)
       Hysteresis loss at %.f Hertz , Ph = 25 W instead
       of %.f W \n ",f2,Ph2);
```

Scilab code Exa 3.14 To find efficiency at full load and half load at power factor of unity 80 percentage lagging and leading and also maximum efficiency ant output at which maximum efficiency occurs

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
```

```
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.14
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 S = 10 * 10 ^ 3;          // Rating of the Single
      Transformer in VA
17 f = 50;                    // Frequency in Hertz
18 Pc = 110;                  // Required input no-load at
       normal voltage in Watts (Core loss)
19 Psc = 120;                 // Required input Short-
      circuit at full-load current in Watts (copper
      loss or short circuit loss)
20
21
22 // CALCUATIONS
23 // case (a) for Unity power factor
24
25 cos_theta1 = 1;

      // Unity Power factor
26 K1 = 1.0;

      // Full load
27 K2 = 0.5;

      // Half load
28 eta_11 = 100 * (K1*S*cos_theta1)/((K1*S*cos_theta1)+
      Pc+( K1 ^ 2 )*Psc);          // Efficiency at
      unity factor and full load ( beacuse taken k1 = 1
      ) in percentage
29 eta_12 = 100 * (K2*S*cos_theta1)/((K2*S*cos_theta1)+
```

```
     Pc+( K2 ^ 2 )*Psc);          // Efficiency at
     unity factor and half load ( beacuse taken k2 =
     0.5 ) in percentage
30
31 // case (b) for 0.8 power factor lagging
32
33 cos_theta2 = 0.8;

     // 0.8 power factor lagging
34 eta_21 = 100 * (K1*S*cos_theta2)/((K1*S*cos_theta2)+
     Pc+( K1 ^ 2 )*Psc);          // Efficiency at 0.8
      power factor lagging and full load ( beacuse
     taken k1 = 1 ) in percentage
35 eta_22 = 100 * (K2*S*cos_theta2)/((K2*S*cos_theta2)+
     Pc+( K2 ^ 2 )*Psc);          // Efficiency at 0.8
      power factor lagging and half load ( beacuse
     taken k2 = 0.5 ) in percentage
36
37 // Case (c) for 0.8 poer factor leading
38
39 eta_31 = eta_21;                        //
     Efficiency at 0.8 power factor leading and full
     load will be same as the Efficiency at 0.8 power
     factor lagging and full load in percentage
40 eta_32 = eta_22;                        //
     Efficiency at 0.8 power factor leading and half
     load will be same as the Efficiency at 0.8 power
     factor lagging and half load in percentage
41
42 // Case (d) Maximum Efficiency assumed that unity
     power factor
43 // Psc = Pc At Maximum Efficiency
44
45 eta_41 = 100 * (K1*S*cos_theta1)/((K1*S*cos_theta1)+
     Pc+Pc);              // Maximum Efficiency at unity
     factor and full load ( beacuse taken k1 = 1 ) in
     percentage
46
```

```
47  // Case ( e ) Maximum Efficiency assumed that 0.8
        power factor lagging
48  // Psc = Pc At Maximum Efficiency
49
50  eta_51 = 100 * (K1*S*cos_theta2)/((K1*S*cos_theta2)+
        Pc+Pc);              // Maximum Efficiency at unity
        factor and full load ( beacuse taken k1 = 1 ) in
        percentage
51
52  // Case ( f ) Maximum Efficiency assumed that 0.8
        power factor leading
53  // Psc = Pc At Maximum Efficiency
54
55  eta_61 = eta_51;

        // Maximum Efficiency at 0.8 power factor leading
         and full load will be same as the Maximum
        Efficiency at 0.8 power factor lagging and full
        load in percentage
56  out1 = K1*S*cos_theta1;
                                                    //
        Output at which maximum efficiency occurs at
        unity power factor at full load in Watts
57  out2 = K1*S*cos_theta2;
                                                    //
        Output at which maximum efficiency occurs at 0.8
        power factor lagging at full load in Watts
58  out3 = K1*S*cos_theta2;
                                                    //
        Output at which maximum efficiency occurs at
        unity power factor leading at full load in Watts
59
60  // DISPLAY RESULTS
61
62  disp("EXAMPLE : 3.14 : SOLUTION :-") ;
63  printf("\n (a.1) Efficiency at unity power factor
        and full load , eta = %.2f Percent \n ",eta_11);
64  printf("\n (a.2) Efficiency at unity power factor
```

```
        and half load , eta= % .2 f Percent \n",eta_12);
65 printf("\n (b.1) Efficiency at 0.8 power factor
        lagging and full load , eta = %.2f Percent \n ",
        eta_21);
66 printf("\n (b.2) Efficiency at 0.8 power factor
        lagging and half load , eta= % .2 f Percent \n",
        eta_22);
67 printf("\n (c.1) Efficiency at 0.8 power factor
        leading and full load , eta = %.2f Percent \n ",
        eta_31);
68 printf("\n (c.2) Efficiency at 0.8 power factor
        leading and half load , eta= % .2 f Percent \n",
        eta_32);
69 printf("\n  (d)  Maximum Efficiency at unity power
        factor and full load , eta = %.2f Percent \n ",
        eta_41);
70 printf("\n  (e)  Maximum Efficiency at 0.8 power
        factor lagging and full load , eta = %.2f Percent
        \n ",eta_51);
71 printf("\n  (f)  Maximum Efficiency at 0.8 power
        factor leading and full load , eta = %.2f Percent
        \n ",eta_61);
72 printf("\n  (g)  Output at which maximum efficiency
        occurs at unity power factor at full load = %.f W
        \n ",out1);
73 printf("\n  (h)  Output at which maximum efficiency
        occurs at 0.8 power factor lagging at full load =
        %.f W \n ",out2);
74 printf("\n  (i)  Output at which maximum efficiency
        occurs at 0.8 power factor leading at full load =
        %.f W \n ",out3);
75 printf("\n IN THE ABOVE PROBLEM MAXIMUM EFFICIENCY
        AND THE OUTPUT AT WHICH THE MAXIMUM EFFICIENCY
        OCCURS IS NOT CALCULATED IN THE TEXT BOOK \n")
```

Scilab code Exa 3.15 To find all day efficiency

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.15
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15 // Refer figure 3.17 page no. 101
16
17 S = 500 * 10 ^ 6;                        // Rating of
      power transformer in VA
18 V1 = 400 * 10^3;                    // HV side
      rating of the power transformer in Volts
19 V2 = 131 * 10^3;                    // LV side
      rating of the power transformer in Volts
20 pcu = 5;                            // Rated Copper
      loss in Percentage
21 pi = 1;                             // Rated Core
      loss in Percentage
22
23
24 // CALCULATIONS
25
26 Pcu = S*(pcu/100);                              //
      Rated Copper loss in Watts
27 Pi = S*(pi/100);                                //
      Rated Core loss in Watts
28 kt = 0.25*3 + 0.75*3 + 1*3 + 0.5*3 + 1.0*3 + 0.25*6
```

49

```
        + 1.0*3;                    // From graph figure 3.17
            page no. 101
29  out = S*kt;                                          //
            Output energy in kilo−watt−hour
30  kt2 = 0.54375;                                       //
            From graph figure 3.17 page no. 101
31  eloss = 24*Pi + S*kt2;                               //
            Energy required in losses in kilo−watt−hour {
            Energy required in losses = 24*Pi + sigma(copper
            loss ∗ duration)}
32  eta = 100*(out/(out+eloss));                         //
            All day efficiency
33
34
35  // DISPLAY RESULTS
36
37  disp("EXAMPLE : 3.15: SOLUTION :−");
38  printf("\n (a) All day efficiency = %.2f percent \n"
            ,eta)
```

Scilab code Exa 3.16 To find percentage regulation at full load UPF and at 60 percentage lagging and leading pf

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.16
10
11 clear ; clc ; close ; // Clear the work space and
            console
```

```
12
13
14  // GIVEN DATA
15
16  S = 20 * 10 ^ 3;                        // Rating  of  the
        Step−down  Transformer  in  VA
17  f = 50;                                 // Frequency  in
        Hertz
18  V = 200;                                // Normally
        supplied  Voltage  of  Step−down  Transformer  in
        Volts
19  Vsc = 100;                              // Potential
        difference  when  Secondary  being  Short−  Circuited
        in  Volts
20  Isc = 10;                               // Primary
        Current  when  Secondary  being  Short−  Circuited  in
        Amphere
21  Cos_theta_sc = 0.28;                    // Power  factor
        when  Secondary  being  Short−  Circuited
22
23
24  // CALCULATIONS
25
26  I = S/V;                                // Rated
        primary  current  in  Amphere
27  Wsc = Vsc * Isc * Cos_theta_sc;         // Power
        loss  when  Secondary  being  Short−  Circuited  in
        Watts
28  R = Wsc/(Isc ^ 2);                      //
        Resistance  of  Transformer  referred  to  primary
        side  in  Ohms
29  Z = Vsc/Isc;                            //
        Referred  Impedence  in  Ohms
30  X = sqrt((Z^2)-(R^2));                  //
        Leakage  Reactance  referred  to  primary  side  in
        Ohms
31  Er = (I*R)/V;                           // Per
        unit  Resistance  in  Ohms
```

```
32  Ex = (I*X)/V;                              // Per
        unit Reactance in Ohms
33  Cos_theta1 = 1.0;                          // Unity
        Power factor
34  Cos_theta2 = 0.6;                          // 0.6
        Power factor Lagging
35  Cos_theta3 = 0.6;                          // 0.6
        Power factor Leading
36  Sin_theta1 = 0.0;                          // Unity
        Power factor
37  Sin_theta2 = 0.8;                          // 0.6
        Power factor Lagging
38  Sin_theta3 = 0.8;                          // 0.6
        Power factor Leading
39  E1 = (Er*Cos_theta1)+(Ex*Sin_theta1);      // pu
        Regulation at Unity Power factor
40  E2 = (Er*Cos_theta2)+(Ex*Sin_theta2);      // pu
        Regulation at 0.6 Power factor Lagging
41  E3 = (Er*Cos_theta3)-(Ex*Sin_theta3);      // pu
        Regulation at 0.6 Power factor Leading
42
43
44  // DISPLAY RESULTS
45
46  disp("EXAMPLE : 3.16 : SOLUTION :−") ;
47  printf("\n (a) pu Regulation at Unity Power factor ,
        E = %.1f \n ",E1);
48  printf("\n (b) pu Regulation at 0.6 Power factor
        Lagging , E= % .2f \n",E2);
49  printf("\n (c) pu Regulation at 0.6 Power factor
        Leading , E= % .2f \n",E3);
```

Scilab code Exa 3.17 To find load pf at which secondary terminal voltage will be minimum

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.17
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 S = 500;                              // Rating of the
       3-Phase transformer in kVA
17 V1 = 11 * 10 ^ 3;                     // Votage rating
       of the 3-Phase transformer on HV side in Volts
18 V2 = 400;                            // Votage rating
       of the 3-Phase transformer on LV side in Volts
19 f = 60;                              // Frequencyin
       Hertz
20 eta = 98;                            // Maximum
       Efficency of the Transformer in Percentage
       Operating at 80% full load and Unity Power factor
21 K = 0.8;                             // Beacuse 80%
       Full load
22 x = 1.0;                             // Unity Power
       factor
23 Ex = 4.5;                            // Percentage
       impedance
24
25
26 // CALCULATIONS
27
28 Out = S * K * x;                        // Output in
```

```
                 KiloWatts at 80% full load and Unity Power factor
29  Inp = Out/(eta/100);                      // Input in
                 KiloWatts at full load and Unity Power factor
30  Total_loss = Inp - Out;                   // Total loss
                 at full load in KiloWatts
31  Cu_loss = Total_loss/2;                   // Copper loss
                  in KiloWatts at 80% full load and Unity Power
                 factor
32  Pcu = Cu_loss/(K ^2 );                    // Full load
                 Copper loss in KiloWatts
33  Er = Pcu/S;                               // Per unit
                 Resistance
34  theta = atand((Ex/100)/Er);              // Power
                 factor angle at secondary terminal voltage is
                 minimum in Degrees
35  Pf = cosd(theta);                         // Load power
                 factor for minimum volatge of the secondary
                 terminal
36
37
38  // DISPLAY RESULTS
39
40  disp("EXAMPLE : 3.17 : SOLUTION :-") ;
41  printf("\n (a) Load power factor for minimum volatge
                  of the secondary terminal , cos(theta) = %.4f
                 lagging \n ",Pf);
```

Scilab code Exa 3.19 To find how will sharing of the two transformers if the total load of 400kW at UPF

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
```

```scilab
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.19
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 Sa = 200;                    // Rating of the TWO 1-Phase
         Transformer in kVA
17 Z1 = 0.005 + 0.08 * %i  // Equivalent Impedance of
      the Transformer-1 in Per-Unit
18 Z2 = 0.0075 + 0.04 * %i // Equivalent Impedance of
      the Transformer-2 in Per-Unit
19 P = 400;                     // Total load in kiloWatts
20 Cos_theta = 1.0;         // Unity power factor
21
22
23 // CALCULATIONS
24
25 kVA = P/Cos_theta;        // kVA rating of the
      Transformer
26 S = kVA;                     // kVA rating of the
      Transformer
27 S1 = ( Z2/(Z1+Z2) )*S;    // Load shared by
      Transformer-1 in kVA
28 S2 = S - S1;                 // Load shared by
      Transformer-2 in kVA
29
30
31 // DISPLAY RESULTS
32
33 disp("EXAMPLE : 3.19 : SOLUTION :-") ;
34 printf("\n (a) Load shared by Transformer-1 , S1 = %
      .2f+j(%.2f) kVA \n ",real(S1),imag(S1));
```

```
35  printf("\n (b )Load  shared  by  Transformer −2  ,  S2 = %
        .2 f+j%.2 f  kVA \n ",real(S2),imag(S2));
36  printf("\n\n      [ TEXT BOOK SOLUTION  IS  PRINTED
        WRONGLY (  I  verified  by  manual  calculation  )]\n"
        );
37  printf("\n          WRONGLY PRINTED ANSWERS ARE := ( a )
        S1 = (−131.90)+j(38.47)kVA  instead  of %.2 f+j(%.2 f
        )  kVA \n ",real(S1),imag(S1));
38  printf("\n                                          ( b )
        S2 = (268.1)+j(.38047)kVA   instead  of %.2 f+j%.2 f
        kVA \n ",real(S2),imag(S2));
```

Scilab code Exa 3.20 To find current flowing in the primary winding

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  // First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.20
10
11  clear ; clc ; close ; // Clear  the  work  space  and
        console
12
13
14  // GIVEN DATA
15
16  V1 = 110;                 // Primary  voltage  of  the
        Two  Transformers  the  two  primaries  are  connected
        in  parallel  in  Volts
17  I1 = 2.0;                 // Primary  Current  in
        Amphere
```

```
18  P1 = 40;                      // Primary power intake in
        Watts
19  V2 = 28;                      // secondary voltage of the
        Two Transformers the two secondary are connected
        in phase opposition in Volts
20  I2 = 6.8;                     // secondary Current in
        Amphere
21  P2 = 180;                     // secondary power intake in
         Watts
22  a = 110/220;                  // Turn ratio of the
        Transformer
23
24
25  // CALCULATIONS
26
27  theta_o = acosd((a*P1)/(a*I1*V1));
                                  // Primary Power factor
        angle in Degrees
28  Io = 1.0 * (cosd(theta_o)-sind(theta_o)* %i);
                                  // No-load current in
        individual transformer in Amphere
29  theta_sc = acosd((a*P2)/(a*I2*V2));
                                  // Secondary Power factor
        angle in Degrees
30  i_sc = I2 * ( cosd(theta_sc)-sind(theta_sc)* %i);
                // Secondary current in Amphere
31  I_sc = (1/a)*i_sc;
                                            // referred
        Secondary current in each of the primary side in
        Amphere
32  It1 = Io + I_sc;
                                            // LT
        winding current in the 1st Transformer in Amphere
33  It2 = Io - I_sc;
                                            // LT
        winding current in the 2nd Transformer in Amphere
34  In1 = It1 + It2;
                                            // The
```

```
        current flowing on paralel connected LT winding (
        This is same as total no-load current in the two
        Transforemer) in Amphere
35
36
37  // DISPLAY RESULTS
38
39  disp("EXAMPLE : 3.20 : SOLUTION :-") ;
40  printf("\n (a) LT ( Primary ) winding current in the
        1st Transformer , It1 = %.3f+j(%.4f) A \n ",real
        (It1),imag(It1));
41  printf("\n (b) LT ( Primary ) winding current in the
        2nd Transformer , It2= %.3f+j%.5f A \n",real(It2
        ),imag(It2));
42  printf("\n (c) LT winding are connected in parallel ,
        the current flowing on paralel connected LT
        winding , In1 = %.3f+j(%.5f) A \n",real(In1),imag(
        In1));
```

Scilab code Exa 3.21 To find calculate the kVA rating and currents of autotransformers as shown in figure 3 31b and 3 31c

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.21
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
```

```scilab
13
14 // GIVEN DATA
15 // Refer figures 3.31(a), 3.31(b) and 3.31(c):- Page
       no. 121
16
17 VaH = 220;                         // HV side Voltage of
       the two winding Transformer in volts for case(a)
18 VaL = 110;                         // LV side Voltage of
       the two winding Transformer in volts for case(a)
19 VbH = 330;                         // HV side Voltage of
       the two winding Transformer in volts for case(b)
20 VbL = 220;                         // LV side Voltage of
       the two winding Transformer in volts for case(b)
21 VcH = 330;                         // HV side Voltage of
       the two winding Transformer in volts for case(c)
22 VcL = 110;                         // LV side Voltage of
       the two winding Transformer in volts for case(c)
23 S = 1.5;                           // Ratings of the the
       two winding Transformer in kVA
24 I1 = 6.8;                          // Rated current in HV
        side in Amphere
25 I2 = 13.6;                         // Rated current in LV
        side in Amphere
26
27
28 // CALCULATIONS
29 // for case(a):- figure 3.31(b) page no. 121
30
31 IbH = I2;                               // Current of Auto-
       Transformer in HV side in Amphere
32 IbL = I1 + I2;                          // Current of Auto-
       Transformer in LV side in Amphere
33 KVA_b_L = (VbL*IbL)/1000;          // LV side kVA
       rating of the Auto-Transformer in kVA
34 KVA_b_H = (VbH*IbH)/1000;          // HV side kVA
       rating of the Auto-Transformer in kVA
35
36 // for case(b):- figure 3.31(c) page no. 121
```

```
37
38  IcH = I1;                               // Current of Auto
        −Transformer in HV side in Amphere
39  IcL = I1 + I2;                          // Current of Auto
        −Transformer in LV side in Amphere
40  KVA_c_L = (VcL*IcL)/1000;               // LV side kVA
        rating of the Auto−Transformer in kVA
41  KVA_c_H = (VcH*IcH)/1000;               // HV side kVA
        rating of the Auto−Transformer in kVA
42
43
44  // DISPLAY RESULTS
45
46  disp("EXAMPLE : 3.21 : SOLUTION :−") ;
47  printf("\n (a.1) Current of Auto−Transformer in HV
        side for case (b) , IH = %.1f A \n ",IbH);
48  printf("\n        Current of Auto−Transformer in LV
        side for case (b), IL= % .1f A \n",IbL);
49  printf("\n (a.2) LV side kVA rating of the Auto−
        Transformer for case (b), KVAL = % .3f kVA \n ",
        KVA_b_L);
50  printf("\n        HV side kVA rating of the Auto−
        Transformer for case (b), KVAH= % .3f kVA \n",
        KVA_b_H);
51  printf("\n (b.1) Current of Auto−Transformer in HV
        side for case (c) , IH = %.1f A \n ",IcH);
52  printf("\n        Current of Auto−Transformer in LV
        side for case (c) , IL= % .1f A \n",IcL);
53  printf("\n (b.2) LV side kVA rating of the Auto−
        Transformer for case (c), KVAL = % .3f kVA \n ",
        KVA_c_L);
54  printf("\n        HV side kVA rating of the Auto−
        Transformer for case (c) , KVAH= % .3f kVA \n",
        KVA_c_H);
```

Scilab code Exa 3.22 To find current supplied by the common winding kVA rating of the auto transformer and voltage on secondary if common winding are open

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.22
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 S = 10 * 10 ^ 3;                    // Rating of the
       Two-winding Transformer in VA
17 V1 = 2000;                         // HV side voltage
        of the Two-winding Transformer in Volts
18 V2 = 200;                          // LV side voltage
        of the Two-winding Transformer in Volts
19 V_A_H = 2200;                      // Two-winding
       Transformer is connected to auto transformer HV
       side in Volts
20 V_A_L = 200;                       // Two-winding
       Transformer is connected to auto transformer LV
       side in Volts
21 f = 50;                            // Frequency in
       Hertz
22
23
24 // CALCULATIONS
25 // for finding (a)
```

```
26
27  I2 = S/V2;                              // Rated LV side
        current  of  winding  for  Step-up  Auto  transformer
        in  Amphere
28  I1 = S/V1;                              // Rated HV side
        current  of  winding  for  Step-up  Auto  transformer
        in  Amphere
29  IaH = I2;                               // The HV side
        current  in  the  Auto-Transformer  for  Full-load  in
        Amphere
30  IaL = I2 + I1 ;                         // The LV side
        current  in  the  Auto-Transformer  for  Full-load  in
        Amphere
31  VL = V1;                                // LV side
        voltage  in  Volts
32  VH = V1 + V2;                           // HV side
        voltage  in  Volts
33  KVA_a_L = (VL*IaL)/1000;                // kVA rating of
        LV SIDE
34  KVA_a_H = (VH*IaH)/1000;                // kVA rating of
        HV SIDE
35
36  // For  finding  (b)
37
38  IbH = I1;                               // HV side Rated
        current  through  the  Auto-Transformer  in  Amphere
39  IbL = I1 + I2;                          // LV side Rated
        current  through  the  Auto-Transformer  in  Amphere
40  KVA_b_L = (V_A_L*IbL)/1000;             // kVA rating of
        LV SIDE  as  output  Auto-Transformer
41  KVA_b_H = (V_A_H*IbH)/1000;             // kVA rating of
        HV SIDE  as  output  Auto-Transformer
42
43  // case  (c)
44
45  V = V1;                                 // Voltage on
        the  Secondary ,  if  the  Commom  windings  are  open
46
```

```
47
48  // DISPLAY RESULTS
49
50  disp("EXAMPLE : 3.22 : SOLUTION :−") ;
51  printf("\n (a.1)  HV side Curent supplied by the
        common windings , IH = %.f A \n ",IaH);
52  printf("\n (a.2)  LV side Curent supplied by the
        common windings , IL= %.f A \n",IaL);
53  printf("\n (b.1)  KVA rating of LV SIDE as output
        Auto−Transformer , KVAL = %.f kVA \n ",KVA_b_L);
54  printf("\n (b.2)  KVA rating of HV SIDE as output
        Auto−Transformer , KVAH= %.f kVA \n",KVA_b_H);
55  printf("\n  (c)    Voltage on the Secondary , if the
        Commom windings are open , V = %.f V \n ",V);
```

Scilab code Exa 3.23 To find current and phase voltages and the voltage across the neutral assuming ideal transformer

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.23
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 S = 100;                                      // Rating
```

```
      of  the  3−Phase  Transformer  in  kVA
17  VH = 11;                                      // HV side
      voltage  in  kilo−Volts
18  VL = 440;                                     // LV side
       voltage  in  Volts
19  Vl = 400;                                     // Line
      voltage  in  Volts
20  ZA = 0.6;                                     // Line
      impedance  in  line  A  in  Ohms
21  ZB = 0.6*(0.8 + 0.6 * %i);                    // Line
      impedance  in  line  B  in  Ohms
22  ZC = 0.6*(0.5 - 0.866 * %i);                  // Line
      impedance  in  line  C  in  Ohms
23
24
25  // CALCULATIONS
26
27  Vp = Vl/sqrt(3);

      // Phase  voltage  in  Volts
28  VAB = Vl * exp( %i * 0 * %pi/180);
                                 // Line  Voltage
      across  line  A  and  B  in  Volts
29  VBC = Vl * exp( %i * (-120) * %pi/180);
                                 // Line  Voltage  across
      line  B  and  C  in  Volts
30  VCA = Vl * exp( %i * 120 * %pi/180);
                                 // Line  Voltage
      across  line  C  and  A  in  Volts
31  VAN = (Vl/sqrt(3)) * exp( %i * (-30) * %pi/180);
                          // Phase  Voltage  across  line  A
      and  Neutral  in  Volts
32  VBN = (Vl/sqrt(3)) * exp( %i * (-150) * %pi/180);
                          // Phase  Voltage  across  line  B
      and  Neutral  in  Volts
33  VCN = (Vl/sqrt(3)) * exp( %i * (90) * %pi/180);
                          // Phase  Voltage  across  line  C
      and  Neutral  in  Volts
```

```
34  IA = VAN/ZA;

       // Line current in line A in Amphere
35  IB = VBN/ZB;

       // Line current in line B in Amphere
36  IC = VCN/ZC;

       // Line current in line C in Amphere
37  IN = IA + IB + IC ;
                                                                //
       Current in the Neutral in Amphere
38  Y = (1/ZA)+(1/ZB)+(1/ZC);
                                                         // Net
       Admittance in mho
39  VN = IN/Y;

       // Neutral Potential in Volts
40  VDA = VAN - VN;

       // Voltage drops across the ZA in Volts
41  VDB = VBN - VN;

       // Voltage drops across the ZB in Volts
42  VDC = VCN - VN;

       // Voltage drops across the ZC in Volts
43
44
45  // DISPLAY RESULTS
46
47  disp("EXAMPLE : 3.23 : SOLUTION :−") ;
48  printf("\n (a.1) Line current in line A  , IA = %.f<
       %.f A \n ",abs(IA),atand(imag(IA),real(IA)));
49  printf("\n (a.2) Line current in line B  , IB = %.f<
       %.2f A \n",abs(IB),atand(imag(IB),real(IB)));
50  printf("\n (a.3) Line current in line C  , IC = %.f<
       %.f A \n ",abs(IC),atand(imag(IC),real(IC)));
```

```
51  printf("\n (b.1) Phase Voltage across line A and
        Neutral , VAN = %.f<%.f V \n",abs(VAN),atand(imag
        (VAN),real(VAN)));
52  printf("\n (b.2) Phase Voltage across line B and
        Neutral , VBN = %.f<%.f V \n ",abs(VBN),atand(
        imag(VBN),real(VBN)));
53  printf("\n (b.3) Phase Voltage across line C and
        Neutral , VCN = %.f<%.f V \n",abs(VCN),atand(imag
        (VCN),real(VCN)));
54  printf("\n (c)    Neutral Potential , VN = %.1f<%.2f
        V \n ",abs(VN),atand(imag(VN),real(VN)));
55  printf("\n\n      [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
56  printf("\n       WRONGLY PRINTED ANSWERS ARE :- (a)
        IC = 385<-90.1 V instead of %.f<%.f A \n ",abs(IC
        ),atand(imag(IC),real(IC)));
57  printf("\n                                      (b)
        VN = 230.5<78.17 V  instead of %.1f<%.2f V \n ",
        abs(VN),atand(imag(VN),real(VN)) );
58  printf("\n From Calculation of the IC, rest all the
        Calculated values in the TEXT BOOK is WRONG
        because of the IC value is WRONGLY calculated and
         the same used for the further Calculation part \
        n")
```

Scilab code Exa 3.24 To find secondary line voltage and current primary and secondary phase current and the output for star star connection star delta connection delta delta connection and delta star connection

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
```

```scilab
6
7  // CHAPTER : 3 : TRANSFORMERS
8
9  // EXAMPLE : 3.24
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 VL = 11000;                          // Line-line voltage
       of the 3 identical 1-phase Transformer in Volts
17 IL = 10;                             // Line current of
       the 3 identical 1-phase Transformer in Amphere
18 a = 10;                             // Ratio of trun per
       phase of the 3 identical 1-phase Transformer
19
20
21 // CALCULATIONS
22 // For case (a) STAR-STAR
23
24 VPp_a = VL/sqrt(3);                 // Primary phase
       volatge in Volts
25 IPp_a = IL;                         // Primary phase
       current in Amphere
26 VSp_a = VPp_a/a;                    // Secondary phase
       voltage in Volts
27 ISp_a = a*IPp_a;                    // Secondary phase
       current in Amphere
28 ISl_a = ISp_a;                      // Secondary line
       current in Amphere
29 VSl_a = VSp_a*sqrt(3);              // Secondary line
       voltage in Volts
30 Out_a = sqrt(3)*VSl_a*ISl_a/1000; // Output in kVA
31
32 // For case (b) STAR-DELTA
33
```

```
34  VPp_b = VL/sqrt(3);                   // Primary phase
        volatge in Volts
35  IPp_b = IL;                           // Primary phase
        current in Amphere
36  VSp_b = VPp_a/a;                      // Secondary phase
        voltage in Volts
37  ISp_b = a*IPp_b;                      // Secondary phase
        current in Amphere
38  ISl_b = sqrt(3)*ISp_b;                // Secondary line
        current in Amphere
39  VSl_b = VSp_b;                        // Secondary line
        voltage in Volts
40  Out_b = sqrt(3)*VSl_b*ISl_b/1000;     // Output in kVA
41
42  // For case (c) DELTA–DELTA
43
44  VPp_c = VL;                           // Primary phase
        volatge in Volts
45  IPp_c = IL/sqrt(3);                   // Primary phase
        current in Amphere
46  VSp_c = VPp_c/a;                      // Secondary phase
        voltage in Volts
47  ISp_c = a*IPp_c;                      // Secondary phase
        current in Amphere
48  ISl_c = sqrt(3)*ISp_c;                // Secondary line
        current in Amphere
49  VSl_c = VSp_c;                        // Secondary line
        voltage in Volts
50  Out_c = sqrt(3)*VSl_c*ISl_c/1000;     // Output in kVA
51
52  // For case (d) DALTA–STAR
53
54  VPp_d = VL;                           // Primary phase
        volatge in Volts
55  IPp_d = IL/sqrt(3);                   // Primary phase
        current in Amphere
56  VSp_d = VPp_d/a;                      // Secondary phase
        voltage in Volts
```

```scilab
57  ISp_d = a*IPp_d;                        // Secondary phase
        current in Amphere
58  ISl_d = ISp_d;                          // Secondary line
        current in Amphere
59  VSl_d = sqrt(3)*VSp_d;                  // Secondary line
        voltage in Volts
60  Out_d = sqrt(3)*VSl_d*ISl_d/1000; //Output in kVA
61
62
63  // DISPLAY RESULTS
64
65  disp("EXAMPLE : 3.24 : SOLUTION :-") ;
66  printf("\n For STAR-STAR Connection \n\n (a.1)
        Secondary line voltage = %.f V \n ",VSl_a);
67  printf("\n (a.2) Secondary line current = % .f A \n"
        ,ISl_a);
68  printf("\n (a.3) Primary phase current = %.f A \n ",
        IPp_a);
69  printf("\n (a.4) Secondary phase current = %.f A \n"
        ,ISp_a);
70  printf("\n (a.5) Output = %.2f kVA \n ",Out_a);
71  printf("\n For STAR-DELTA Connection \n\n  (b.1)
        Secondary line voltage = % .f V \n",VSl_b);
72  printf("\n (b.2) Secondary line current = %.f A \n "
        ,ISl_b);
73  printf("\n (b.3) Primary phase current = %.f A \n",
        IPp_b);
74  printf("\n (b.4) Secondary phase current = %.f A \n
        ",ISp_b);
75  printf("\n (b.5) Output = % .2f kVA \n",Out_b);
76  printf("\n For DELTA-DELTA Connection \n\n (c.1)
        Secondary line voltage = %.f V \n ",VSl_c);
77  printf("\n (c.2) Secondary line current = %.2f A \n"
        ,ISl_c);
78  printf("\n (c.3) Primary phase current = %.2f A \n "
        ,IPp_c);
79  printf("\n (c.4) Secondary phase current = %.1f A \n
        ",ISp_c);
```

```
80  printf("\n (c.5) Output = %.1f kVA \n ",Out_c);
81  printf("\n For DELTA–STAR Connection \n\n (d.1)
        Secondary line voltage = % .2f V \n",VSl_d);
82  printf("\n (d.2) Secondary line current = %.1f A \n
        ",ISl_d);
83  printf("\n (d.3) Primary phase current = %.2f A \n",
        IPp_d);
84  printf("\n (d.4) Secondary phase current  = %.1f A \
        n ",ISp_d);
85  printf("\n (d.5) Output = % .1f kVA \n",Out_d);
```

Chapter 4

Direct Current Machines

Scilab code Exa 4.1 To find maximum induced EMF in the armature conductor

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.1
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 N = 600;                        // Speed of the driven
       Machine in RPM
17 D = 2;                          // Diameter of the
       Machine in Meter
```

```
18  L = 0.3;                          // Length  of  the  Machine
        in  Meter
19  Bm = 1.0;                         // Flux  Density  in  Weber
        per  Meter−Square
20
21
22  // CALCULATIONS
23
24  n = N/60;                         // Revolution  per  second
25  v = %pi * D * n;                  // Peripheral  velocity
        in  Meter  per  second
26  E = Bm * v * L;                   // Maximum  EMF  induced
        in  the  Conducter  in  Volts
27
28
29  // DISPLAY  RESULTS
30
31  disp("EXAMPLE :  4.1  : SOLUTION :−") ;
32  printf("\n  (a)  Maximum  EMF  induced  in  the  Conducter
        ,  E = %.3f  V  \n ",E);
33  printf("\n\n      [ TEXT BOOK SOLUTION  IS  PRINTED
        WRONGLY ( I  verified  by  manual  calculation  )]\n"
        );
34  printf("\n        WRONGLY PRINTED ANSWERS ARE :− (a)
        Induced  EMF,  E = 2.826  V  instead  of %.3f  A  \n ",E
        );
35  printf("\n From  Calculation  of  the  peripheral
        velocity(v),  rest  all  the  Calculated  values  in
        the  TEXT BOOK  is  WRONG  because  of  the  peripheral
        velocity(v)  value  is  WRONGLY  calculated  and  the
        same  used  for  the  further  Calculation  part  \n")
```

Scilab code Exa 4.2 To find EMF induced

```
1
```

```scilab
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.2
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 p = 8;                              // Number of the
       poles in Dc machine
17 a = 8;                              // Number of the
       Parallel path
18 N = 500;                            // Rotation per
       minute in RPM
19 phi = 0.095;                        // Average flux in
       air gap in Weber per meter
20 Za = 1000;                          // Total number of
       the Conductor in Armature
21
22
23 // CALCUALTIONS
24
25 n = N/60;                           // Rotation (
       Revolution) per Second
26 E = (p/a)*n*phi*Za;                 // EMF induced in
       Volts
27
28
29 // DISPLAY RESULTS
30
31 disp("EXAMPLE : 4.2 : SOLUTION :-") ;
```

```
32  printf("\n (a) EMF induced , E = %.1f A \n ",E);
```

Scilab code Exa 4.3 To find the number of conductors in parallel path

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.3
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  E = 420;                    // EMF induced in Volts
17  N = 900;                    // Rotation speed in RPM
18  phi = 0.06;                 // Flux per pole in Weber
        per pole
19  Two_p = 4;                  // Total number of poles
20
21
22  // CALCULATIONS
23
24  n = N/60;                              // Revolution Per
        second
25  Zc = E/(Two_p*phi*n);               // Number of the
        Conductor in Parallel Path
26
27
```

```
28  // DISPLAY RESULTS
29
30  disp("EXAMPLE : 4.3 : SOLUTION :−") ;
31  printf("\n (a) Number of the Conductor in Parallel
        Path , Zc = %.2 f Conductors nearly 117 conductors
        \n ",Zc);
```

Scilab code Exa 4.4 To find torque

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.4
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  L = 0.3;                // Length of the Machine in
        Meter
17  Ia = 10;                // Current through The
        Conductors in Ampheres
18  N = 10;                 // Number of the Conductors in
        each Slot
19  Za = 24;                // Number of the Slots
20  Bav = 0.6;              // Average Flux Density in Telsa
21  D = 0.1;                // Machine Daimeter in Meter
22
```

```
23
24  // CALCULATIONS
25
26  F = N*Ia*Bav*L;                    // Force due to the
        Single Slot in Newton
27  T = (Bav*L*Ia*N*D*Za)/2            // Torque produced in
        the Machine in Newton-Meter
28
29
30  // DISPLAY RESULTS
31
32  disp("EXAMPLE : 4.4 : SOLUTION :-") ;
33  printf("\n (a) Torque produced in the Machine , T = %
        .1 f N-m \n",T);
```

Scilab code Exa 4.5 To find useful flux per pole when the armature is lap and wave connected

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.5
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  p = 4;                    // Number of the Poles in the DC
```

```
           machine
17  Nt = 100;                  // Number of the turns in the Dc
           machine
18  N = 600;                   // Rotation speed of the DC
        machine in RPM
19  E = 220;                   // EMF generated in open circuit
        in Volts
20  Z = 200;                   // Total number of the Conductor
        in armature
21
22
23  // CALCUALTIONS
24  // For case (a) Lap Connected
25
26  a = 4;                                 // Number of the
        Poles in the DC machine
27  n = N/60;                              // Revolution per
        second
28  phi_a = (E*a)/(p*Z*n);          // Useful flux per
        pole when Armature is Lap connected in Weber
29
30  // For case (b) Wave Connected
31
32  a = 2;                                 // Number of the
        Poles in the DC machine
33  phi_b = (E*a)/(p*Z*n);          // Useful flux per
        pole when Armature is Wave connected in Weber
34
35
36  // DISPLAY RESULTS
37
38  disp("EXAMPLE : 4.5 : SOLUTION :-") ;
39  printf("\n (a) Useful flux per pole when Armature is
        Lap connected , phi = %.1 f Wb  \n ",phi_a);
40  printf("\n (B) Useful flux per pole when Armature is
        Lap connected , phi = %.3 f Wb  \n ",phi_b);
```

Scilab code Exa 4.6 To find Torque

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.6
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 p = 6;                          // Number of the pole in
      DC Motor
17 Ia = 20;                        // Armature Current in
      Amphere
18 Z = 1000;                       // Number of the
      Conductors
19 a = 6;                          // Number of the
      Parallel paths
20 phi = 25 * 10 ^ -3;             // Flux per pole in
      Weber
21
22
23 // CALCULATIONS
24
25 T = (p/a)*((Z*Ia*phi)/(2*%pi));         // Deleloped
      Torque in Newton−Meter
```

```
26
27
28  // DISPLAY RESULTS
29
30  disp("EXAMPLE : 4.6 : SOLUTION :-") ;
31  printf("\n (a) Developed Torque in an Six-pole DC
        Motor , T = %.1f N-m \n ",T);
```

Scilab code Exa 4.7 To find reactance voltage

```
1
2   // ELECTRICAL MACHINES
3   // R.K. Srivastava
4   // First Impression 2011
5   // CENGAGE LEARNING INDIA PVT. LTD
6
7   // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9   // EXAMPLE : 4.7
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  p = 2;                      // Number of the Pole
17  N = 1000;                   // Rotation speed of the
        Armature in RPM
18  Ia = 20;                    // Armature Current in
        Amphere
19  CS = 36;                    // Commutator Segments
20  BW = 1.4;                   // Brush width is 1.4 times
        of the Commutator Segments
21  L = 0.09 * 10 ^ -3;         // Inducatnce of the each
```

```
     Armature  Coil
22
23
24  // CALULATIONS
25
26  a = p;                           // Number  of  the  Parallel
       paths (Equal  to  number  of  poles  because  Lap
       Connected  Armature)
27  n = N/60;                        // Revoultion  per  second
28  I = Ia/2;                        // Current  Through  the  each
       Conductor  in  Amphere
29  v = n * CS;                      // Peripheral  Velocity  of
       Commutator  in  Commutator  segments  per  Seconds
30  Tc = BW/v;                       // Time  of  the  Commutation
       in  Seconds
31  Er = (L*2*I)/Tc;                 // Reactance  voltage  in
       Volts
32
33
34  // DISPLAY  RESULTS
35
36  disp("EXAMPLE :  4.7  : SOLUTION :-") ;
37  printf("\n (a) Reactance  voltage  assuming  Linear
       Commutation  , Er = %.4f V \n",Er);
38  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
      WRONGLY ( I verified  by  manual  calculation )]\n"
      );
39  printf("\n       WRONGLY PRINTED ANSWERS ARE :- (a) Tc
       = 0.014 s instead  of %.4f s \n",Tc);
40  printf("\n                                          (b) Er
       = 1.2857 V instead  of %.4f V\n",Er);
41  printf("\n From Calculation  of  the  Time  of
       commutation (Tc), rest  all  the  Calculated  values
       in  the TEXT BOOK is WRONG because  of  the  Time  of
       commutation (Tc) value  is WRONGLY calculated  and
       the  same  used  for  the  further  Calculation  part \n
       ")
```

Scilab code Exa 4.8 To find approximate time of commutation

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.8
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 N = 800;                    // Rotation speed of the
      Commutator in RPM
17 D = 50;                     // Diameter in Centimeter
18 BW = 1.5;                   // Brush Width in Centimeter
19
20
21 // CALCULATIONS
22
23 r = D/2;                    // Radius in Centimeter
24 n = N/60;                   // Revoultion per second
25 w = (2 * %pi)*n;            // Angular velocity
26 v = w*r;                    // Peripheral Speed in
      centimeter per second
27 Tc = (BW/v)*1000;           // Time of the
      Commutation in Second
28
```

```
29
30  // DISPLAY RESULTS
31
32  disp("EXAMPLE : 4.8 : SOLUTION :−") ;
33  printf("\n (a) Time of the Commutation , Tc = %.4f
        ms \n",Tc);
```

Scilab code Exa 4.9 To find Ampere turn per pole the demagnetizing armature turn per pole cross magnetizing armature turn per pole and ampere turn of compensating winding when lap and wave conncted

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.9
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  p = 4;                      // Number of the pole in
         the Generator
17  Ia = 100;                   // supplying Current by
         the Generator in Amphere
18  Za = 500;                   // Armature conductor
19  beta = 8;                   // Brush shift in
        degrees
20  If = 5;                     // Current in the
```

```
        Seperately exicted field winding
21  ratio = 0.7;                        // Ratio of Pole arc to
        Pole pitch
22
23
24  // CALCULATIONS
25  // For case (a) Lap winding
26
27  a_a = p;                                               //
        Number of the Parallel Paths
28  AT_a = (Za*Ia)/(2*a_a*p);                              //
        Amphere turns per pole
29  ATd_a = (beta*Za*Ia)/(360*a_a);                        //
        Demagnetizing Armature Amphere turns per pole
30  ATc_a = ((1/p)-(beta/180))*((Za*Ia)/(2*a_a));     //
        CrossMagnetizing Armature Amphere turns per pole
31  ATw_a = ratio*AT_a;                                    //
        Amphere turns of Compensating winding
32
33  // For case (b) Wave winding
34
35  a_b = p/2;                                             //
        Number of the Parallel Paths
36  AT_b = (Za*Ia)/(2*a_b*p);                              //
        Amphere turns per pole
37  ATd_b = (beta*Za*Ia)/(360*a_b);                        //
        Demagnetizing Armature Amphere turns per pole
38  ATc_b = ((1/p)-(beta/180))*((Za*Ia)/(2*a_b));     //
        CrossMagnetizing Armature Amphere turns per pole
39  ATw_b = ratio*AT_b;                                    //
        Amphere turns of Compensating winding
40
41
42  // DISPLAY RESULTS
43
44  disp("EXAMPLE : 4.9 : SOLUTION :-") ;
45  printf("\n For LAP winding \n\n (a.1) Amphere turns
        per pole , AT = %.1f AT \n",AT_a);
```

```
46  printf(”\n (a.2) Demagnetizing Armature Amphere
        turns per pole, ATd = %.1f AT \n”,ATd_a);
47  printf(”\n (a.3) Cross−Magnetizing Armature Amphere
        turns per pole, ATc = %.1f AT \n”,ATc_a);
48  printf(”\n (a.4) Amphere turns of Compensating
        winding, ATw = %.1f AT \n”,ATw_a);
49  printf(”\n For WAVE winding \n\n (b.1) Amphere turns
         per pole, AT = %.f AT \n”,AT_b);
50  printf(”\n (b.2) Demagnetizing Armature Amphere
        turns per pole, ATd = %.2f AT \n”,ATd_b);
51  printf(”\n (b.3) Cross−Magnetizing Armature Amphere
        turns per pole, ATc = %.f AT \n”,ATc_b);
52  printf(”\n (b.4) Amphere turns of Compensating
        winding, ATw = %.1f AT \n”,ATw_b);
```

Scilab code Exa 4.10 To find the number of turns on each interpole

```
1
2   // ELECTRICAL MACHINES
3   // R.K.Srivastava
4   // First Impression 2011
5   // CENGAGE LEARNING INDIA PVT. LTD
6
7   // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9   // EXAMPLE : 4.10
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  p = 6;                          // Number of the Poles
17  P = 100 * 10 ^ 3;               // Power rating of the
```

```
         DC machine in KiloWatts
18  V = 440;                          // Voltage rating of the
        DC machine in Volts
19  Z = 500;                          // Total number of the
        Armature Conductor
20  Ig = 1.0 * 10 ^ -2;              // Interpolar Air gap in
        Meter
21  Bi = 0.28;                        // Interpolar Flux
        Densist in Weber per Meter-Square
22  mue_0 = 4*%pi*10^ -7;            // Permeability of the
        air in Henry/Meter
23
24
25  // CALCULATIONS
26
27  Ia = P/V;                         // Full
        load current in Amphere
28  a = p;                            // Number
        of the Parallel path (Equal to p because LAP
        WINDING)
29  ATi = (Z*Ia)/(2*a*p)+((Bi*Ig)/mue_0);     // Amphere
        turns for each Interpole
30  Nc = ATi/Ia;                      // Number
        of turns per pole of interpole
31
32
33  // DISPLAY RESULTS
34
35  disp("EXAMPLE : 4.10 : SOLUTION :-") ;
36  printf("\n (a) Amphere turns for each Interpole , ATi
        = %.2f AT \n",ATi);
37  printf("\n (b) Number of turns per pole of interpole
        , Nc = %.2f turns per pole nearly %.f turns per
        pole \n",Nc,Nc);
```

Scilab code Exa 4.11 To find voltage at the terminal of the machine and critical resistance

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.11
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 printf("\n EXAMPLE : 4.11 : \n\n           Given Data
        between the Field current and Open−Circuit EMF
       generated by DC shunt wound Generator \n");
17 printf("\n If(A)    0        1        2        3
       4        5        6  \n");
18 printf("\n Voc(v)   10       90       170      217.5
       251     272.5    281 \n");
19 N = 1000;                   // Speed of an DC Shunt
       wound generator on open circuit in RPM
20 Rf = 50;                    // Shunt field resistance in
        Ohms
21
22
23 // CALCULATIONS
24 // Refer Figure 4.20:− Page no. 180
25
26 Vt = 277.17;                      // Terminal Voltage
       in Volts from Figure 4.20 (The slope of the
       Resistance line Rf cuts the OCC at this Voltage [
```

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```
         point ])
27  Voc_r = 90;                        // Critical Open
        circuit voltage in Volts from Figure 4.20 page no
        . 180
28  If_r = 1.0;                        // Critical Field
        current in Amphere from Figure 4.20 page no. 180
29  Rc = Voc_r/If_r;                   // Crictical field
        Resistance in Ohms
30
31
32  // DISPLAY RESULTS
33
34  printf(" \n\n           SOLUTION :-\n") ;
35  printf("\n (a) Crictical field Resistance , Rc = %.f
        Ohms \n",Rc);
```

Scilab code Exa 4.12 To find critical resistance and terminal voltage

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  //  First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.12
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  printf("\n EXAMPLE : 4.12 : \n\n           Given Data
```

```
           between  the  Field  current  and  Open−Circuit  EMF
        generated  by  DC  Machine  \n");
17  printf("\n  If(A)      0           0.25            0.5             1.0
             1.5          2.0         2.5        3.0  \n");
18  printf("\n  Voc(v)   8          43             77           151
             198         229        253       269\n");
19  N = 600;                           // Speed  of  an  DC  Shunt
        wound  generator  on  open  circuit  in  RPM
20  Rf1 = 100;                         // Shunt  field  resistance
        in  Ohms
21  Rf2 = 125;                         // Shunt  field  resistance
        in  Ohms
22
23
24  // CALCULATIONS
25  //  Refer  Figure  4.21:−  Page  no.  181
26
27  Vt1 = 253.33;                           // Terminal  Voltage
        in  Volts  correspounding  to  field  resistance  of
        100  Ohms  from  Figure4.21  Page  no.  181  (The  slope
        of  the  Resistance  line  Rf  cuts  the  OCC  at  this
        Voltage  [point])
28  Vt2 = 213.33;                           // Terminal  Voltage
        in  Volts  correspounding  to  field  resistance  of
        125  Ohms  from  Figure  4.21  Page  no.  181  (The  slope
         of  the  Resistance  line  Rf  cuts  the  OCC  at  this
        Voltage  [point])
29  Voc_r = 151;                          // Critical  Open
        circuit  voltage  in  Volts  from  Figure  4.20
30  If_r = 1.0;                           // Critical  Field
        current  in  Amphere  from  Figure  4.20
31  Rc = Voc_r/If_r;                      // Crictical  field
        Resistance  in  Ohms
32
33
34  // DISPLAY  RESULTS
35
36  printf("  \n\n              SOLUTION  :−\n")  ;
```

```
37  printf ("\n  (a)   Crictical  field  Resistance ,  Rc  = %.
        f  Ohms  \n" , Rc ) ;
38  printf ("\n (b.1)  Terminal  Voltage  correspounding  to
        field  resistance  of  100  Ohms  is  %.2f  V  \n  " ,  Vt1 )
        ;
39  printf ("\n (b.1)  Terminal  Voltage  correspounding  to
        field  resistance  of  125  Ohms  is  %.2f  V  \n  " ,  Vt2 )
        ;
```

Scilab code Exa 4.13 To find load current

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  // First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  4  :  DIRECT  CURRENT  MACHINES
8
9  // EXAMPLE  :  4.13
10
11  clear  ;  clc  ;  close  ;  // Clear  the  work  space  and
        console
12
13
14  // GIVEN  DATA
15
16  N1  =  1200;              // Rotation  speed  of  the
        Separately  excited  Generator  in  RPM  at  case  (1)
17  Ia1  =  100;              // Current  supplied  by  the
        Generator  in  Amphere
18  V1  =  220;              // Opearting  Volatge  of  the
        Generator  in  Volts
19  Ra  =  0.08;              // Armature  Resistance  in
        Ohms
```

```
20  N2 = 1000;                    // Rotation speed of the
        Separately excited Generator in RPM at case (2)
21  Vb = 2.0;                     // Total Brush drop in Volts
22
23
24  // CALCULATIONS
25
26  RL = V1/Ia1;                          // Load
        resistance in Ohms
27  E1 = V1 + Vb + (Ra * Ia1);            // Back EMF
         at case (1) in Volts
28  E2 = (N2/N1)*E1;                      // Back
      EMF at case (2) in Volts (Excitation is Constant)
29  Ia2 = (E2 - Vb)/(RL + Ra);            // New load
        current in Amphere for case (2)
30
31
32  // DISPLAY RESULTS
33
34  disp("EXAMPLE : 4.13 : SOLUTION :-") ;
35  printf("\n (a) New load current at %.f RPM , Ia2 = %
        .2 f A \n",N2,Ia2);
```

Scilab code Exa 4.14 To find current and percentage change in speed of the machine

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.14
```

```
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  I = 50;                              // Curent supplied by
        the Separately Excitated Generator in Amphere
17  V = 250;                             // Dc bus bar in Volts
18  phi_1 = 0.03;                        // Useful Flux in
        Weber
19  Ra = 0.5;                            // Armature Resistance
         in Ohms
20  phi_2 = 0.029;                       // New(Changed) Flux
        in Weber
21
22
23  // CALCULATIONS
24
25  Vd = I * Ra;
        // Voltage drop in the Armature in Volts
26  E1 = V + Vd;
        // EMF Generated in Volts
27  E2 = (phi_2/phi_1)*E1;
        // EMF Generated in Volts immediately after flux
        changes but speed will remains same
28  Ia = (E2 - V)/Ra;                                        //
         Armature Current in Amphere immediately after
        flux changes
29  perct = 100 * (( phi_1 - phi_2)/phi_2);
        // Percenatge change in the speed of the machine
        that is required to restore the original Armature
         current but EMF raised to the original value and
         its Proportional to the speed and flux
30
31
32  // DISPLAY RESULTS
```

```
33
34  disp("EXAMPLE : 4.14 : SOLUTION :-") ;
35  printf("\n (a) Armature Current immediately after
        flux changes, Ia = %.1f A \n",Ia);
36  printf("\n (b) Percenatge change in the speed of the
         machine (that is required to restore the
        original Armature current) is %.2f Percenatge \n"
        ,perct);
```

Scilab code Exa 4.15 To find sharing of the two transformers when the load is 800kVA

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.15
10
11  clear ; clc ; close ; // Clear the work space and
      console
12
13
14  // GIVEN DATA
15
16  S = 500 * 10 ^ 3;                    // Rating of the
      Generator-1 and Generator-2
17  VI = 800 * 10 ^ 3'                   // Actual load
18
19
20  // CALCULATIONS
21  //For Case (a)
```

```
22
23  Voc_a = 500;                                    // Open-
        circuit EMF Generator-1 and Generator-2 in Volts
24  I = 1000;                                       // Full
        load current in Amphere
25  perct_1a = 2/100;                               //
        Percenatge fall of the Voltage in Generator-1
26  perct_2a = 3/100;                               //
        Percenatge fall of the Voltage in Generator-2
27  V1a = Voc_a - (perct_1a * Voc_a);               //
        Voltage in the Generator-1 in Volts when it falls
         to 2% at fully loaded
28  V2a = Voc_a - (perct_2a * Voc_a);               //
        Voltage in the Generator-2 in Volts when it falls
         to 3% at fully loaded
29  // From Chacteristics can be assumed linear as, for
        Generator 1 is V = 500 + ((500-490)*I1)/(0-1000),
         V = -0.01*I1+500 and for Generator 2 is V = 500
        + ((500-485)*I2)/(0-1000), V = 0.015*I2+500
30  // When sharing load of 800KVA at voltage, the load
        current will be I = I1+I2 = (800*1000)/V
31  // From above equations we get I1 = 1.5*I2 thus,
        2.5*I2 = (800*1000)/V
32  // Putting the above equations in the Generator 2
        equation we get V = -0.015*((800*1000)/(2.5*V))
        +500 solving we get, 25*V^2 - 12500V + 120000 = 0
33  V_a = poly ([120000 -12500 25],'x','coeff');
                                       // Expression for the
        load Voltage in Quadratic form
34  r_a = roots (V_a);

        // Value of the load Voltage in Volts (neglecting
         lower value)
35  I_a = VI/r_a(1,1);
36  I2_a = I_a/2.5;
37  I1_a = 1.5*I2_a;
38
39  // For Case (b)
```

```scilab
40
41  perct = 2/100;                                    //
        Percenatge  fall  of  the  Voltage  in  Generator-1and
        Generator-2
42  Voc_1b = 500;                                     // Open-
        circuit  EMF  Generator-1  in  Volts
43  Voc_2b = 505;                                     // Open-
        circuit  EMF  Generator-2  in  Volts
44  I = 1000;                                         //  Full
        load  current  in  Amphere
45  V1 = Voc_1b - (perct * Voc_1b);                   //
        Voltage  in  the  Generator-1  in  Volts  when  it  falls
         to  2%  at  fully  loaded
46  V2 = Voc_2b - (perct * Voc_2b);                   //
        Voltage  in  the  Generator-2  in  Volts  when  it  falls
         to  2%  at  fully  loaded
47  // From  Chacteristics  can  be  assumed  linear  as,  for
        Generator  1  is  V = 500 + ((500-490)*I1)/(0-1000),
         V = -0.01*I1+500  and  for  Generator  2  is  V = 505
        + ((505-494.5)*I2)/(0-1000),  V = -0.0101*I2+505
48  // When  sharing  load  of  800KVA  at  voltage,  the  load
        current  will  be  I = I1+I2 = (800*1000)/V
49  // From  above  equations  we  get  V = -0.01*I1 + 500,
        I1 = -V/0.01 + 500/0.01 = 50000 - 100*V, V =
        -0.0101*I2 + 505  and  I2 = 505/0.0101 - V/.0101 =
        50000-99.0099*V
50  // Putting  the  above  equations  in  the  Current  I
        equation  we  get  I = I1+I2 = (800*1000)/V =
        2*50000-199.0099*V  solving  we  get,  199.0099*V^2 -
         100000V + 800000 = 0
51  V_b = poly ([800000 -100000 199.0099],'x','coeff');
                            // Expression  for  the  load
        Voltage  in  Quadratic  form
52  r_b = roots (V_b);

        // Value  of  the  load  Voltage  in  Volts (neglecting
         lower  value)
53  I_b = VI/r_b(1,1);
```

```
54  I1_b = 50000-100*r_b(1,1)
55  I2_b = 50000-99.0099*r_b(1,1)
56
57
58  // DISPLAY RESULTS
59
60  disp("EXAMPLE : 4.15: SOLUTION :−");
61  printf("\n For case (a) Having open−circuit EMfs of
        500V but their voltage falls to 2 percent and 3
        percent when fully loaded Load Voltage,\n\n
        Load Voltage = %.2f V \n\n        Load current = %
        .2f A \n\n        Individual currents are %.2f A
        and %.2f A \n",r_a(1,1),I_a,I1_a,I2_a)
62  printf("\n For case (b) Having open−circuit EMfs of
        500V and 505V but their governors have identical
        speed regulation of 2 percent when fully loaded
        Load Voltage,\n\n        Load Voltage = %.2f V \n\n
            Load current = %.2f A \n\n        Individual
        currents are %.2f A and %.2f A \n",r_b(1,1),I_b,
        I1_b,I2_b)
63  printf("\n\n      [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
64  printf("\n        WRONGLY PRINTED ANSWERS ARE :− For
        case(b) Load voltage = 493.35 V A instead of %.2f
         V \n ",r_b(1,1));
65  printf("\n

        Load current = 1634.73 A instead of %.2f A \n ",
        I_b)
66  printf("\n

        Individual currents 665 A and 1153.5 A instead of
        %.2f A and %.2f \n ",I1_b,I2_b)
67  printf("\n For Case (b):− From Calculation of the
        Load Voltage (V), rest of all the Calculated
        values in the TEXT BOOK is WRONG because of the
        value Load Voltage (V) is WRONGLY calculated and
```

the same used for the further Calculation part \n
")

Scilab code Exa 4.16 To find the graded resistance

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.16
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 Out_hp = 20;                        // Output of the
       Motor in HP
17 eta = 90/100;                       // Full load
       efficiency of the Motor
18 V = 220;                            // Motor voltage in
       Volts
19 ns = 5;                             // Number of the step
        of Starter
20 Rf = 220;                           // Field Resistance
       in Ohms
21 cr = 1.8;                           // Lowest Current
       rating is 1.8 times of the Full load current
22 Cu = 5/100;                         // Total Copper loss
       is 5% of the Input
```

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```
23
24
25  // CALCULATIONS
26
27  Out = 20 * 746;                          ..        //
        Output  of  the  Motor  in  Watt
28  Inp = (Out/eta);                                   // Input
         of  the  Motor  in  KiloWatt
29  I = Inp/Rf;                                        // Full−
        Load  Current  in  Amphere
30  Cu_l = Inp*Cu;                                     // Total
         Copper  loss  in  Watts
31  olf = (V ^ 2)/Rf;                                  // Ohmic
         loss  in  the  Fiels  in  the  Watts
32  Acu = Cu_l - olf;                                  //
        Armature  Copper  loss  in  Watts
33  Ra = Acu/(I * I);                                  //
        Armature  Resistance  in  Ohms
34  I2 = I * cr;                                       // Lower
         Current  in  Amphere
35  n = ns - 1;                                        //
        Number  of  the  Resistance
36  gama = ( (I2 * Ra)/Rf ) ^ (1/(n + 1));            //
        Current  Ratio
37  I1 = I2/gama;                                      //
        Initial  Current  in  amphere
38  R1 = V/I1;                                         //
        Initial  Resistance  in  Ohms
39  R2 = gama * R1;                                    //
        Initial  Resistance  in  Ohms
40  r1 = R1 - R2;                                      //
        Graded  Resistance  in  Ohms
41  R3 = gama * R2;                                    //
        Initial  Resistance  in  Ohms
42  r2 = gama * r1;                                    //
        Graded  Resistance  in  Ohms
43  r3 = gama ^ 2 * r1;                                //
        Graded  Resistance  in  Ohms
```

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```
44  r4 = gama ^ 3 * r1;                      //
        Graded  Resistance  in  Ohms
45
46
47  // DISPLAY  RESULTS
48
49  disp ("EXAMPLE :  4.16  :  SOLUTION :−") ;
50  printf ("\n (a) Graded  Resistances  are  %.4 f  Ohms, %.4
        f  Ohms, %.4 f  Ohms  and  %.4 f  Ohms  \n", r1, r2, r3, r4);
```

Scilab code Exa 4.17 To find lower current limit and resistance each section

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT. LTD
6
7  // CHAPTER :  4  :  DIRECT  CURRENT  MACHINES
8
9  // EXAMPLE :  4.17
10
11  clear  ;  clc  ;  close  ;  // Clear  the  work  space  and
        console
12
13
14  // GIVEN  DATA
15
16  I = 30;                        // Initial  starting
        Current  in  Amphere
17  ns = 5;                        // Number  of  Steps  of
        the  starter
18  V = 500;                       // Operating  Voltage  of
        the  DC Shunt  Motor  in  Volts
```

```
19  I1 = 50;                            // Peak(Upper) Current
        limit in Amphere
20  Ra = 1.0;                           // Armature Circuit
        resistance in Ohms
21
22
23  // CALCULATIONS
24
25  R1 = V / I;                         // Initial
        Resistance in Ohms
26  gama = ( Ra/R1) ^ (1/(ns-1));       // Current Ratio
27  I2 = gama * I1;                     // Lower Current
         limit in Amphere
28  r1 = R1 * (1-gama);                 // Graded
        Resistances in Ohms
29  r2 = gama * r1;                     // Graded
        Resistances in Ohms
30  r3 = gama * r2;                     // Graded
        Resistances in Ohms
31  r4 = gama * r3;                     // Graded
        Resistances in Ohms
32
33
34  // DISPLAY RESULTS
35
36  disp("EXAMPLE : 4.17 : SOLUTION :-") ;
37  printf("\n (a)Graded Resistances are %.2f Ohms, %.4f
        Ohms, %.4f Ohms and %.4f Ohms \n",r1,r2,r3,r4);
```

Scilab code Exa 4.18 To find resistance steps in series motor starter

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
```

```scilab
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.18
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 V = 500;
       // Operating voltage of the DC series motor in
       Volts
17 P_hp = 10;
       // Operating Power in HP
18 Il = 40;
       // Lower currents limit in Amphere
19 Ih = 60;
       // Higher currents limit in Amphere
20 f = 0.5/100;
       // Motor flux rises by 0.5% per amphere
21 Rt = 0.8;
       // Motor terminal resistance in Ohms
22 eta = 90/100;
       // Motor efficiency
23
24 // CALCULATIONS
25
26 E1 = V-Il*Rt;
       // Induced EMF E1 in Volts
27 // Induced EMF, E2 = 500-60(0.8+r4) = 500 - 60*R4
       where r4 is the fourth-step resistance, and R4 =
       0.8+r4 and E1 = 1.1*E2 , 500 - 40*0.8 =
       1.1*(500-60(0.8+r4)) , 500-32 = 550-66*R4 thus we
       get , R4 = (550-500+32)/66 refer page no. 197
28 R4 = (V-(E1/1.1))/Ih;
```

```
29  r4 = R4 - Rt;
                                                        //
        Fourth−step  resistance  in  ohms
30  R3 = (V-((V-Il*R4)/1.1))/Ih;
31  r3 = R3 - R4;
                                                        //
        Third−step  resistance  in  ohms
32  R2 = (V-((V-Il*R3)/1.1))/Ih;
33  r2 = R2 - R3;
                                                        //
        Second−step  resistance  in  ohms
34  R1 = (V-((V-Il*R2)/1.1))/Ih;
35  r1 = R1 - R2;
                                                        //
        First−step  resistance  in  ohms
36
37
38  // DISPLAY RESULTS
39
40  disp("EXAMPLE : 4.18: SOLUTION :−");
41  printf("\n (a) The  resistance  steps  in  series  motor
        stater  are %.3f Ohms,%.4f Ohms, %.3f Ohms and %.2
        f Ohms \n",r1,r2,r3,r4)
```

Scilab code Exa 4.19 To find speed power torque of the motor

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.19
```

```scilab
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 Vac = 250;                          // Operating AC Voltage
       in Volts
17 V = 220;                            // Operating Voltage of
       the separately excited DC motor in Volts
18 fa = 30;                            // Firing Angle in
       Degree
19 Out_hp = 20;                        // DC Motor Output in HP
20 La = 20 * 10 ^ -3;                  // Armature Inducatnce
       in Henry
21 Ra = 0.15;                          // Armature Resistance
       in Ohms
22 E_cons = 0.2;                       // EMF Constant in Volts
       /RPM
23 eta = 90/100;                       // Motor Operating
       Efficiency
24 N = 1000;                           // Rotational Speed of
       the Motor in RPM
25
26
27 // CALCULATIONS
28
29 out = 20 * 746;                           // DC Motor
       Output in Watt
30 Vt = ((Vac*2*sqrt(2))/%pi)*cosd(fa);      // Average
       Terminal volatge in Volts
31 Ia = out/(V*eta);                         // Rated
       Current in Amphere
32 E = Vt - ( Ia * Ra );                     // Back EMF
       in Volts
33 n = E/E_cons;                             // Speed of
       the Motor in RPM
```

```
34 e_cons = (E_cons*60)/ ( 2 * %pi);        // EMF
      Constant in Volts−Second per radians
35 T = e_cons * Ia;                          // Devolped
      Torque in Newton−Meter
36 pi = (E*Ia)+(Ia^2*Ra);                    // Power
      intake in Watts
37 pi_v = Vt * Ia;                           // Power
      intake in Watts (Verification)
38
39
40 // DISPLAY RESULTS
41
42 disp("EXAMPLE : 4.19 : SOLUTION :−") ;
43 printf("\n (a) Speed of the Motor , N = %.2f RPM \n",
      n);
44 printf("\n (b) Devolped Torque , T = %.2f N−m \n",T);
45 printf("\n (b) Power intake at Rated current and
      Firing angle of %.f deg , VI = %.1f W \n",fa,pi);
46 printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
      WRONGLY ( I verified by manual calculation )]\n"
      );
47 printf("\n        WRONGLY PRINTED ANSWERS IS :− (a) T
      = 114.07 N−m instead of 143.91 N−m \n" );
```

Scilab code Exa 4.20 To find the firing angle and no load speed at 0 and 30 deg firing angle

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
```

```scilab
9  // EXAMPLE : 4.20
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 N = 1500;                          // Speed of the
       separately excited DC Motor in RPM
17 Out_hp = 100;                      // Output of the DC
       Motor in HP
18 V = 500;                           // Motor operating
       Volatge in Volts
19 VL = 440;                          // 3-phase Line-line
       Voltage in Volts
20 f = 50;                            // Frequency in Hertz
21 Ra = 0.0835;                       // Armature Resistance
       in Ohms
22 La = 5.7 * 10 ^ -3;                // Armature Inductance
       in Henry
23 eta = 89/100;                      // Operating Efficiency
       of the Motor
24 E_cons = 0.35;                     // EMF constant in Volts
        per RPM
25
26
27 // CALCULATIONS
28 // For case (a)
29
30 Out = Out_hp * 746;                    // Output of the
       DC Motor in Watts
31 Ia = Out/(V*eta);                      // Rated Current
       in Amphere
32 Vph = VL/sqrt(3);                      // Phase Voltage
       in Volts
33 a = (3*Vph*sqrt(6)) / %pi;             // Constant
34 E = N * E_cons;                        // Back EMF at
```

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```
          Rated speed
35  V = E + (Ia * Ra);                        // Terminal
          Volatge in Volts
36  alpa = acosd(V/a);                        // Firing Angle
37
38  // For case (b)
39  // Assumed that No load current is about 12% of full
          load current
40
41  Io = ( 0.12 * Ia );                       // No load
          current in Amphere
42  V_b1 = a * cosd(0);                       // Terminal
          Voltage at Firing Angle 0 deg
43  E_b1 = V_b1 + (Io * Ra);                  // Back EMF
          at Firing Angle 0 deg
44  N_b1 = E_b1/E_cons;                       // No load
          speed at Firing Angle 0 deg
45  V_b2 = a * cosd(30);                      // Terminal
          Voltage at Firing Angle 30 deg
46  E_b2 = V_b2 + (Io * Ra);                  // Back EMF
          at Firing Angle 30 deg
47  N_b2 = E_b2/E_cons;                       // No load
          speed at Firing Angle 30 deg
48
49
50  // DISPLAY RESULTS
51
52  disp("EXAMPLE : 4.20 : SOLUTION :-") ;
53  printf("\n  (a)  Firing Angle at Rated speed and
          Rated Motor Current , alpa = %.2f deg \n",alpa);
54  printf("\n (b.1) No load speed at Firing Angle 0 deg
          , N = %.1f RPM \n",N_b1);
55  printf("\n (b.2) No load speed at Firing Angle 30
          deg, N = %.1f RPM \n",N_b2);
```

Scilab code Exa 4.21 To find speed control range of the duty cycle

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.21
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15 // Given that Back EMF is Zero Because Motor is at
       Standstill
16
17 V = 250;                        // DC supply Voltage
        to separately excited DC Motor in Volts
18 Ra = 1.0;                       // Armature
       Resistance in Ohms
19 La = 30 * 10 ^ -3;             // Armature
       Inductance in Henry
20 E_cons = 0.19;                  // Motor (EMF)
       Constant in Volts per RPM
21 Ia = 25;                        // Average Armature
       Current in Amphere
22
23
24 // CALCULATIONS
25
26 V1 = Ia * Ra;                   // Minimum Terminal
       Volatge in Volts
27 alpa_mini = Ia/V;              // Minimum Duty
       Cycle
```

```
28  alpa_max = 1.0;                    // Maximum Duty
        Cycle
29  V2 = V;                            // Maximum Terminal
        Volatge in Volts when Duty cycle (alpa) is 1.0
30  E2 = V2 - (V1 * alpa_max);        // Back EMF at
        Maximum Duty cycle ( i.e alpa = 1.0) in Volts
31  N = E2/E_cons;                    // Speed of the
    Motor
32
33
34  // DISPLAY RESULTS
35
36  disp("EXAMPLE : 4.21 : SOLUTION :−") ;
37  printf("\n (a) Range of the Speed is from 0 RPM to %
        .2f RPM and Range of the Duty Cycle is %.1f to %
        .1f \n",N,alpa_mini,alpa_max);
```

Scilab code Exa 4.22 To find new speed of the motor

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.22
10
11 clear ; clc ; close ; // Clear the work space and
        console
12
13
14 // GIVEN DATA
15
```

```
16  N1 = 1000;                          // Speed  of  the  DC  shunt
        Motor  in  RPM
17  Out_hp = 20;                        // Output  of  the  DC
        shunt  Motor  in  HP
18  V = 220;                            // Motor  operating
        Volatge  in  Volts
19  Ra = 0.9;                           // Armature  Resistance
        in  Ohms
20  Rf = 200;                           // Field  Resistance  in
        Ohms
21  eta = 89/100;                       // Operating  Efficiency
        of  the  Motor
22  Ra_a = 0.2;                         // Resistance  inserted
        to  the  armature  circuit
23
24
25  // CALCULATIONS
26
27  out = Out_hp * 746;                     // Output  of  the
        DC  Motor  in  watts
28  I =  out/(V * eta);                     // Rated  current
        in  Amphere
29  If = V/Rf;                              // Field  current
        in  Amphere
30  Ia1 = I - If;                           // Armature
        current  in  Amphere
31  E1 = V - (Ia1 * Ra);                    // Back EMF in
        Volts
32  // Assuming  that  Torque  and  Armature  current  is
        constant
33  E2 = V - ( Ra + Ra_a ) * Ia1;       // New  Back  EMF
        in  Volts
34  N2 = N1*(E2/E1);                     // New  speed  in
        RPM
35
36
37  // DISPLAY  RESULTS
38
```

```
39  disp("EXAMPLE : 4.22: SOLUTION :−") ;
40  printf("\n (a) New Speed of the Motor , N2 = %.2 f
        RPM \n",N2);
```

Scilab code Exa 4.23 To find new speed of the motor

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.23
10
11 clear ; clc ; close ; // Clear the work space and
        console
12
13
14 // GIVEN DATA
15
16 N1 = 600;                       // Speed of the DC shunt
        Motor in RPM
17 Out_hp = 10;                    // Output of the DC
        shunt Motor in HP
18 V = 220;                        // Motor operating
        Volatge in Volts
19 Ra = 1.5;                       // Armature Resistance
        in Ohms
20 Rf = 250;                       // Field Resistance in
        Ohms
21 eta = 88/100;                   // Operating Efficiency
        of the Motor
22 Rf_a = 50;                      // Resistance inserted
```

```
        to  the  field  circuit
23

24

25  // CALCULATIONS

26

27  out = Out_hp * 746                     // Output  of  the
        DC Motor  in  watts
28  I =   out/(V * eta);                    // Rated  current
        in  Amphere
29  If1 = V/Rf;                             // Field  current
        in  Amphere
30  Ia1 = I - If1;                          // Aramature
        current  in  Amphere
31  E1 = V - Ra*Ia1;                        // Back EMF in
        Volts
32  If2 = V/(Rf+Rf_a);                      // New  Field
        current  in  Amphere  after  50  Ohms  Resistance
        inserted  to  the  field  circuit

33

34  // Refer  page  no.  217  we  have  T1 = K*If1*Ia1
        proportional  to  1/W1^2  and  T1 = K*If2*Ia2
        proportional  to  1/W2^2  thus  T1/T2 = (If1*Ia1)/(
        If2*Ia2) = (W2^2)/(W1^2) = (N2^2)/(N1^2),  Ia2 = (
        If1*Ia1*W1^2)/(If1*W1^2) = (0.88*37.65*N2^2)
        /(0.733*600*600)
35  // Now New EMF E2 is  E2 = V − Ia2*Ra,  E1/E2 = (k*If1
        *N1)/(k*If2*N2),  E2 = (0.733*N2)/(0.88*600) = 220
        − (0.88*37.65*1.5*N2^2)/(0.733*600*600)  Thus  we
        have  0.001388*N2^2 = 220 − 1.833*10^−4*N2
36  N2 = poly ([-220 0.001388 1.833*10^-4],'x','coeff');
                        // Expression  for  the  new  speed
        of  the  motor  in  Quadratic  form
37  r = roots (N2);

        // Value  of  the  New  speed  of  the  motor  in  RPM
38

39

40  // DISPLAY  RESULTS
```

```
41
42  disp("EXAMPLE : 4.23 : SOLUTION :-") ;
43  printf("\n (a) New speed of the motor, N2 = %.2f RPM
          nearly %.f RPM \n",r(2,1),r(2,1));
```

Scilab code Exa 4.24 To find resistances for both dynamic and counter current braking

```
1  // ELECTRICAL MACHINES
2  // R.K. Srivastava
3  // First Impression 2011
4  // CENGAGE LEARNING INDIA PVT. LTD
5
6  // CHAPTER : 4 : DIRECT CURRENT MACHINES
7
8  // EXAMPLE : 4.24
9
10 clear ; clc ; close ; // Clear the work space and
       console
11
12
13 // GIVEN DATA
14
15 N1 = 1000;                    // Speed of the DC shunt
        Motor in RPM
16 Out_hp = 10;                  // Output of the DC
       shunt Motor in HP
17 V = 220;                      // Motor operating
       Volatge in Volts
18 Ra = 0.5;                     // Armature Resistance
       in Ohms
19 Rf = 100;                     // Field Resistance in
       Ohms
20 eta = 90/100;                 // Operating Efficiency
       of the Motor
```

```
21
22
23  // CALCULATIONS
24
25  out = Out_hp * 746;                   // Output of the
        DC Motor in watts
26  I =  out/(V * eta);                   // Rated current
        in Amphere
27  If = V/Rf;                            // Field
        current in Amphere
28  Ia = I-If;                            // Armature
        current in Amphere
29  E = V - (Ia*Ra);                      // Back EMF of
        the Motor in Volts
30  Rd = E/I;                             // Resistance at
        Dynamic Braking in Ohms
31  Rc = (V+E)/I;                         // Resistance at
        Counter Current Braking in Ohms
32
33  // DISPLAY RESULTS
34
35  disp("EXAMPLE : 4.24 : SOLUTION :−") ;
36  printf("\n (a) Resistance at Dynamic Braking , Rd = %
        .2 f Ohms \n",Rd);
37  printf("\n (b) Resistance at Counter Current Braking
        , Rc = %.1 f Ohms \n",Rc);
```

Scilab code Exa 4.25 To find resistance must be added in the field circuit

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
```

```
7   // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9   // EXAMPLE : 4.25
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  V = 220;                              // Motor operating
        Volatge in Volts
17  Ra = 1.0;                             // Armature Resistance
        in Ohms
18  Rf = 220;                             // Field Resistance in
        Ohms
19  Ia1 = 20;                             // Armature Current in
        Amphere
20  N1 = 800;                             // Motor drving speed in
        RPM
21  N2 = 1000;                            // To be obtained speed
        in RPM
22
23
24  // CALCULATIONS
25
26  If = V/Rf;                                          //
        Field Current in Amphere
27  E1 = V - ( Ia1 - If ) * Ra;                         // Back
        EMF E1 at N1 Speed in Volts
28  // Now we have Back EMF E2 at N2 Speed, E2 = 220−Ia2
        *1.0 = 220−Ia2 and the field flux be proportional
        to the field current, since torque is constant
        we get, If2*Ia2 = If1*Ia1 = 20
29  // Thus (220−Ia2)/201 = (If2*N2)/(If1*N1) = If2
        *(1000/(800*1.0)), 220−Ia2 = 201*(10/8)*(20/Ia2)
        = 5000/Ia2 solving this we get Ia2^2 − 220Ia2 +
        2000 = 0
```

```
30  Ia2 = poly ([5000 -220 1],'x','coeff');
                        // Expression for the new
       Armature current in Quadratic form
31  r = roots (Ia2);
                                            // Value
       of the New Armature current in Amphere
32  If2 = If*(Ia1/r(2,1));
                                      // New field
       current in Amphere when New Armature current is
       39.29A
33  Rfn = V/If2;
                                            // New
        field resistance in ohms
34  ERf = Rfn - Rf;
                                      // Extra
       resistance in Ohms
35
36
37  // DISPLAY RESULTS
38
39  disp("EXAMPLE : 4.25 : SOLUTION :-") ;
40  printf("\n (a) Extra resistance should be added in
       the field circuit for raising the speed to %.f
       RPM is = %.2f Ohms \n",N2,ERf);
41  printf("\n\n    [ TEXT BOOK SOLUTION IS PRINTED
       WRONGLY ( I verified by manual calculation )]\n"
       );
42  printf("\n        WRONGLY PRINTED ANSWERS ARE :- (a)
       Ia2 = 39.29 A and 180.71 A instead of %.2f A and
       %.2f A \n ",r(1,1),r(2,1));
43  printf("\n                                    (b)
       Extra resistance required is 212.22 Ohms  instead
        of %.2f Ohms \n ",ERf);
44  printf("\n From Calculation of the New armature
       current (Ia2), rest all the Calculated values in
       the TEXT BOOK is WRONG because of the New
       armature current (Ia2) value is WRONGLY
       calculated and the same used for the further
```

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Scilab code Exa 4.26 To find voltage and current when magnetic circuit unsaturated and saturated

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.26
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 R = 2.0;                          // DC series Motor
       Resistance between the terminals in Ohms
17 V1 = 220;                         // Motor Operating
       voltage in Volts
18 N1 = 500;                         // Rotation Sped of
       the DC series Motor in RPM
19 I1 = 22;                          // Current in Motor
       in Amphere
20 N2 = 600;                         // New Rotation Sped
        of the DC series Motor in RPM
21
22
23 // CALCULATIONS
24 // For case (a) when magnetic circuit is Unsaturated
```

```
25
26  E1 = V1 - (I1 * R);                      // Back EmF at
        N1 Speed in Volts
27  I2_a = (N2/N1)*I1;                       // Current in
        Motor at N2 speed in Amphere
28  E2_a = (E1*I2_a*N2)/(I1*N1);      // Back EmF at N2
        Speed in Volts
29  V2_a = E2_a + (I2_a * R);         // Applied
        Voltage at N2 Speed in Volts
30
31  // For case (b) when magnetic circuit is Saturated
32
33  I2_b = ((N2/N1)^2)*I1;                   // Current in
        Motor at N2 speed in Amphere
34  E2_b = (N2/N1)*E1;                       // Back EmF at
        N2 Speed in Volts
35  V2_b = E2_b + (I2_b * R);                // Applied
        Voltage at N2 Speed in Volts
36
37
38  // DISPLAY RESULTS
39
40  disp("EXAMPLE : 4.26 : SOLUTION :-") ;
41  printf("\n (a.1) Applied Voltage when magnetic
        circuit is Unsaturated ,V2 = %.2f V \n",V2_a);
42  printf("\n (a.2) Current in Motor when magnetic
        circuit is Unsaturated , I2 = %.1f A \n",I2_a);
43  printf("\n (b.1) Applied Voltage when magnetic
        circuit is Saturated ,V2 = %.2f V \n",V2_b);
44  printf("\n (b.2) Current in Motor when magnetic
        circuit is Saturated , I2 = %.2f A \n",I2_b);
```

Scilab code Exa 4.27 To find new speed and current

```
1
```

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```
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 4 : DIRECT CURRENT MACHINES
8
9  // EXAMPLE : 4.27
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 V = 220;                            // DC series Motor
       operating Volatge in Volts
17 Ra = 1.0;                          // Armature Resistance
       in Ohms
18 Rf = 1.0;                          // Field Resistance in
       Ohms
19 I1 = 20;                           // Armature Current in
       Amphere
20 N1 = 1800;                         // Motor drving speed in
        RPM
21 If = 20;                           // Armature Current in
       Amphere
22 Rd = 0.5;                          // Diverter Resistance
       in Ohms
23
24
25 // CALCULATIONS
26
27 E1 = V - ( Ra + Rf ) * I1;                    // Back
       EMF in Volts
28 I2 = sqrt(3)*I1;                              // New
       Armature current in Amphere
29 If2 = ( Rd * I2 )/(Ra + Rd);                  // New
```

```
        field  Current  in  Amphere
30  E2 = V - ( Ra + (1/3))*I1;                    // New
        BAck EMF in Volts
31  N2 = (N1*E2*If)/(E1*If2);                     // New
        Rotation  speed  of  the  Motor  in  RPM
32
33
34  // DISPLAY RESULTS
35
36  disp("EXAMPLE :  4.27 : SOLUTION :−") ;
37  printf("\n   (a)    New  Rotation  speed  of  the  Motor  at
            torque  remains  constant ,  N2 = %. f RPM \n",N2);
38  printf("\n (b.1)   New  Armature  Current  at  torque
        remains  constant ,  I2  = %.2 f A \n",I2);
39  printf("\n (b.2)   New  Field  Current  at  torque
        remains  constant ,  If2  = %.2 f A \n",If2);
```

Scilab code Exa 4.28 To find speed torque efficiency of the motor

```
 1  // ELECTRICAL MACHINES
 2  // R.K.Srivastava
 3  // First Impression 2011
 4  // CENGAGE LEARNING INDIA PVT. LTD
 5
 6  // CHAPTER : 4 : DIRECT CURRENT MACHINES
 7
 8  // EXAMPLE : 4.28
 9
10  clear ; clc ; close ; // Clear the work space and
        console
11
12
13  // GIVEN DATA
14
15  V = 220;                         // DC shunt Motor
```

```scilab
         operating  Volatge  in  Volts
16  Ra = 1.0;                      // Armature  Resistance
        in  Ohms
17  Rf = 220;                      // Field  Resistance  in
        Ohms
18  In1 = 5;                       // No-Load  Current  in
        Amphere
19  N1 = 1000;                     // Motor  drving  speed  in
         RPM
20  inp = 10 * 10 ^ 3;             // Motor  input  in  Watts
21
22
23  // CALCULATIONS
24
25  If = V/Rf;                           // Field
        Current  in  Amphere
26  Ian1 = In1 - If;                     // No load
        Armature  Current  in  Amphere
27  E1 = V - (Ian1 * Ra);                // Back EMF
        in  Volts
28  Iin = inp/V;                         // Motor
        Input  Current  in  Amphere
29  Ia = Iin - If;                       // Armature
        current  in  Amphere
30  E2 = V - (Ia * Ra);                  // New Back
        EMF  in  Volts
31  N2 = (N1*E2)/E1;                     // New
        Rotation  speed  of  the  Motor  in  RPM
32  Pa = E2 * Ia;                        // Developed
         Armature  Power  in  Watts
33  T = Pa/((2*%pi*N2)/60);              // Developed
         Torque  in  Newton-Meter
34  Pi = V * In1;                        // No-Load
        input  Power  in  Watts
35  Pa_cu = Ian1 ^ 2 * Ra;               // No-Load
        Armature  Copper  loss  in  Watts
36  F_loss = Pi - Pa_cu;                 // Fixed
        losses  in  Watts
```

```
37  Pa_cu_load = Ia ^ 2 * Ra;                    // Loaded
        Armature  Copper  loss  in  Watts
38  Total_loss = F_loss + Pa_cu_load;         // Total
        losses  in  loaded  conditions  in  Watts
39  out = inp - Total_loss;                       // Shaft
        output  in  Watts
40  Ts = out/((2*%pi*N2)/60);                  // Shaft
        torque  in  Newton−Meter
41  eta = (out/inp)*100;
42          // Efficiency  in  Percentage
43
44
45  // DISPLAY RESULTS
46
47  disp("EXAMPLE :  4.28  :  SOLUTION :−")  ;
48  printf("\n   (a)  New  Rotation  speed  of  the  Motor  ,
        N2 = %.f RPM \n",N2);
49  printf("\n (b.1)  Developed  Torque ,  T = %.1f  N−m A \n
        ",T);
50  printf("\n (b.2)  Shaft  torque ,  Ts = %.2f  N−m  \n",Ts)
        ;
51  printf("\n   (c)   Efficiency  in  Percentage ,  eta = %.2
        f  percent   \n",eta);
```

Scilab code Exa 4.29 To find efficiency of each machine

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER :  4  :  DIRECT  CURRENT  MACHINES
8
9  // EXAMPLE :  4.29
```

```scilab
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 V = 220;                              // Shunt Motor operating
         Line Volatge in Volts
17 Ra = 0.2;                            // Armature Resistance
       in Ohms
18 Iam = 72;                            // Motor Armature
       current in Amphere
19 I = 12;                              // Line Current in
       Amphere
20 Ifm = 1;                             // Motor field Current
       in Amphere
21 Ifg = 1.5;                           // Generator field
       Current in Amphere
22
23
24 // CALCULATIONS
25
26 Iag = Iam - I;                              //
       Geneartor Armature current in Amphere
27 Pfm = V * Ifm;                           // Loss in
       Motor Field winding in Watts
28 Pfg = V * Ifg;                           // Loss in
       Geneartor Field winding in Watts
29 loss_ma = Iam ^ 2 * Ra;                  // Loss in
       Motor Armature circuit in Watts
30 loss_ga = Iag ^ 2 * Ra;                  // Loss in
       Generator Armature circuit in Watts
31 Em = V - Iam * Ra;                       // Motor
       EMF in Volts
32 Eg = V + Iag * Ra;                       //
       Generator EMF in Volts
33 T_loss = (V*I) - (Ra*Iam^2 + Ra*Iag^2);  // Total
```

```
         Iron  and  Rotational  Loss  in  Watts
34  Pim = (V*Iam)+(V*Ifm);                        // Motor
        input  in  Watts
35  Wc = 0.5 * T_loss;                            // Total
        Iron  and  Rotational  Loss  in  each  Machine  in  Watts
36  Wm = Wc+(Ra*Iam^2)+V*Ifm;                     // Motor
        losses  in  Watts
37  Pom = Pim - Wm;                               // Motor
        output  in  Watts
38  eta_m = (1-(Wm/Pom))*100;                     // Motor
        Efficiency  in  Percentage
39  Pog = V*Iag;                                  //
        Generator  output  in  Watts
40  Wg = Wc+(Ra*Iag^2)+V*Ifg;                     //
        Generator  losses  in  Watts
41  Pin = Pog + Wg;                               //
        Generator  input  power  in  Watts
42  eta_g = (1-(Wg/Pin))*100;                     //
        Generator  Efficiency  in  Percentage
43
44
45  // DISPLAY RESULTS
46
47  disp("EXAMPLE : 4.29 : SOLUTION :-") ;
48  printf("\n (a) Motor  Efficiency  , eta = %.2f
        Percentage \n ",eta_m);
49  printf("\n (b) Generator  Efficiency  , eta = %.2f
        Percantage \n ",eta_g);
50  printf("\n\n      [ TEXT BOOK SOLUTION  IS  PRINTED
        WRONGLY ( I verified  by  manual  calculation  )]\n"
        );
51  printf("\n        WRONGLY PRINTED ANSWERS ARE :- (a)
        Total  Iron  and  Rotational  Loss = 720 W instead  of
        %.1f W \n ",T_loss);
52  printf("\n                                        (b)
        Pim = 15912 W instead  of %.f W \n ",Pim);
53  printf("\n                                        (c)
        Wm = 1371.4  Winstead  of %.1f W \n ",Wm);
```

```
54  printf("\n                                                              (d)
        Pom = 14540.6 W instead  of %.1f W \n ",Pom);
55  printf("\n                                                              (e)
        eta_m = 90.54 Percentage   instead  of %.2f
        Percentage \n ",eta_m);
56  printf("\n                                                              (f)
        eta_g = 93.22 Percentage   instead  of %.2f
        Percentage \n ",eta_g);
57  printf("\n From  Calculation  of  the  Total  Iron  and
        Rotational  Loss  in  each  Machine (Wc) ,  rest  all
        the  Calculated  values  in  the TEXT BOOK  is WRONG
        because  of  the  Total  Iron  and  Rotational  Loss  in
        each  Machine (Wc)  value  is WRONGLY  calculated  and
         the  same  used  for  the  further  Calculation  part \
        n")
```

Scilab code Exa 4.30 To find efficiency of motor and generator and also torque

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  4  :  DIRECT  CURRENT  MACHINES
8
9  // EXAMPLE  :  4.30
10
11 clear ; clc ; close ;  // Clear  the  work  space  and
        console
12
13
14 // GIVEN  DATA
15
```

```
16  Vg = 110;                          // Generator operating
        Volatge in Volts
17  Vm = 102;                          // Motor operating
        Volatge in Volts
18  Vs = 274;                          // Supply Volatge in
        Volts
19  Ra = 1.0;                          // Armature Resistance
        in Ohms for both the Machines
20  Rf = 0.82;                         // Field Resistance in
        Ohms for both the Machines
21  N = 1440;                          // Speed of the Set in
        RPM
22  Ig = 17.5;                         // Generator current in
        Amphere
23  Im = 9.5;                          // Motor current in
        Amphere
24
25
26  // CALCULATIONS
27
28  Pi = Vs * Im;                                      //
        Input power in Watts
29  Pg = Vg * Ig;                                      //
        Output power in Watts
30  Pim = Vm * Im;                                     //
        Power Input to the Motor in Watts
31  Pl = Pi - Pg;                                      //
        Losses in the entire set in Watts
32  Pcu = Im^2*(Ra+2*Rf) + Ig^2*Ra;                    //
        Total Copper loss for both the Machines in Watts
33  P_l = Pi - Pg - Pcu;                               //
        Frictional, Windage and core losses of the both
        Machines in Watts
34  Po = P_l/2;                                        //
        Frictional, Windage and core loss of each
        Machines in Watts
35  eta_m = (1 - ((Po + Im^2*(Ra+Rf))/Pim))*100;       //
        Motor Effiicency in Percentage
```

```
36  Pig = Pg + Po + Ig^2*Ra + Im^2*Rf;                    //
        Generator input in Watts
37  eta_g = (Pg / Pig)*100;                               //
        Generator Effiicency in Percentage
38  T = (Vg*Ig *60)/(2*%pi*N);                            //
        Torque in Newton−Meter
39
40
41  // DISPLAY RESULTS
42
43  disp("EXAMPLE : 4.30 : SOLUTION :−") ;
44  printf("\n (a) Motor Efficiency , eta_m = %.2 f
        percentage \n ",eta_m);
45  printf("\n (b) Generator Efficiency , eta_g = %.2 f
        Percentage \n ",eta_g);
46  printf("\n (c) Torque , T = %.2 f N−m \n ",T);
47  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
48  printf("\n        WRONGLY PRINTED ANSWERS ARE :− (a)
        Generator input = 2307.5 W instead of %. f W \n ",
        Pig);
49  printf("\n                                    (b)
        eta_g = 83.42 Percenatge   instead of %.2 f
        Percentage \n ",eta_g);
50  printf("\n From Calculation of the Generator input ,
        rest all the Calculated values in the TEXT BOOK
        is WRONG because of the Generator input value is
        WRONGLY calculated and the same used for the
        further Calculation part \n")
```

Chapter 5

Induction Machines

Scilab code Exa 5.1 To find slot per pole per phase in each case

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.1
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15 // For Case (a)
16
17 S_a = 30;                   // Total number of Slots
18 m_a = 3;                    // Total number of Poles
19 p_a = 2;                    // Total number of Phases
20
```

```
21  // For Case (b)
22
23  S_b = 60;                       // Total number of Slots
24  m_b = 3;                        // Total number of Poles
25  p_b = 4;                        // Total number of Phases
26
27  // For Case (c)
28
29  S_c = 24;                       // Total number of Slots
30  m_c = 3;                        // Total number of Poles
31  p_c = 4;                        // Total number of Phases
32
33  // For Case (d)
34
35  S_d = 12;                       // Total number of Slots
36  m_d = 3;                        // Total number of Poles
37  p_d = 2;                        // Total number of Phases
38
39
40  // CALCULATIONS
41  // For Case (a)
42
43  spp_a = S_a/(p_a*m_a);                   // Slot per
       poles per phase
44
45  // For Case (b)
46
47  spp_b = S_b/(p_b*m_b);                   // Slot per
       poles per phase
48
49  // For Case (c)
50
51  spp_c = S_c/(p_c*m_c);                   // Slot per
       poles per phase
52
53  // For Case (d)
54
55  spp_d = S_d/(p_d*m_d);                   // Slot per
```

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```
        poles  per  phase
56
57
58  // DISPLAY RESULTS
59
60  disp (" EXAMPLE :  5.1  : SOLUTION :−" )  ;
61  printf ("\n For  case  ( a )  Slot  per  poles  per  phase ,
        spp = %. f   \n " , spp_a ) ;
62  printf ("\n For  case  ( b )  Slot  per  poles  per  phase ,
        spp = %. f   \n " , spp_b ) ;
63  printf ("\n For  case  ( c )  Slot  per  poles  per  phase ,
        spp = %. f   \n " , spp_c ) ;
64  printf ("\n For  case  ( d )  Slot  per  poles  per  phase ,
        spp = %. f   \n " , spp_d ) ;
```

Scilab code Exa 5.2 To find slot per pole per phase phase allocation series
and state whether balanced winding is possible

```
1
2   // ELECTRICAL MACHINES
3   // R.K. Srivastava
4   //  First  Impression  2011
5   // CENGAGE LEARNING  INDIA  PVT. LTD
6
7   // CHAPTER :  5  : INDUCTION MACHINES
8
9   // EXAMPLE :  5.2
10
11  clear  ;  clc  ;  close  ;  // Clear  the  work  space  and
        console
12
13
14  // GIVEN DATA
15  // For  Case  ( a )
16
```

```
17  S_a = 54;                         // Total number of Slots
18  m_a = 3;                          // Total number of Poles
19  p_a = 8;                          // Total number of Phases
20
21  // For Case (b)
22
23  S_b = 32;                         // Total number of Slots
24  m_b = 3;                          // Total number of Poles
25  p_b = 4;                          // Total number of Phases
26
27  // For Case (c)
28
29  S_c = 30;                         // Total number of Slots
30  m_c = 3;                          // Total number of Poles
31  p_c = 4;                          // Total number of Phases
32
33
34  // CALCULATIONS
35  // For Case (a)
36
37  spp_a = S_a/(p_a*m_a);                      // Slot per
        poles per phase
38  l_a = 0 * spp_a;                            // Phase
        allociation Series
39  m_a = 1 * spp_a;                            // Phase
        allociation Series
40  n_a = 2 * spp_a;                            // Phase
        allociation Series
41  o_a = 3 * spp_a;                            // Phase
        allociation Series
42  p_a = 4 * spp_a;                            // Phase
        allociation Series
43  d_a = 0;                                    // d_a = l_a (
        Rounding off)
44  e_a = 2;                                    // e_a = m_a (
        Rounding off)
45  f_a = 4;                                    // f_a = n_a (
        Rounding off)
```

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```
46  g_a = 6;                                    // g_a = o_a (
       Rounding  off )
47  h_a = 9;                                    // h_a = p_a (
       Rounding  off )
48  R_a = e_a - d_a;                            // Phase
       allociation
49  Y_a = f_a - e_a;                            // Phase
       allociation
50  B_a = g_a - f_a;                            // Phase
       allociation
51  R1_a = h_a - g_a;                           // Phase
       allociation
52
53  // For  Case  (b)
54
55  spp_b = S_b/(p_b*m_b);                      // Slot  per
       poles  per  phase
56  l_b = 0 * spp_b;                            // Phase
       allociation  Series
57  m_b = 1 * spp_b;                            // Phase
       allociation  Series
58  n_b = 2 * spp_b;                            // Phase
       allociation  Series
59  o_b = 3 * spp_b;                            // Phase
       allociation  Series
60  d_b = 0;                                    // d_b = l_b (
       Rounding  off )
61  e_b = 2;                                    // e_b = m_b (
       Rounding  off )
62  f_b = 5;                                    // f_b = n_b (
       Rounding  off )
63  g_b = 8;                                    // g_b = o_b (
       Rounding  off )
64  R_b = e_b - d_b;                            // Phase
       allociation
65  Y_b = f_b - e_b;                            // Phase
       allociation
66  B_b = g_b - f_b;                            // Phase
```

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```
          allociation
67
68  // For Case (c)
69
70  spp_c = S_c/(p_c*m_c);                        // Slot per
          poles per phase
71  l_c = 0 * spp_c;                              // Phase
          allociation Series
72  m_c = 1 * spp_c;                              // Phase
          allociation Series
73  n_c = 2 * spp_c;                              // Phase
          allociation Series
74  d_c = 0;                                      // d_b = l_b (
          Rounding off)
75  e_c = 2;                                      // e_b = m_b (
          Rounding off)
76  f_c = 5;                                      // f_b = n_b (
          Rounding off)
77  R_c = e_c - d_c;                              // Phase
          allociation
78  Y_c = f_c - e_c;                              // Phase
          allociation
79
80  // DISPLAY RESULTS
81
82  disp("EXAMPLE : 5.2 : SOLUTION :-") ;
83  printf("\n  For Case (a) Slot per poles per phase  ,
          spp = %.3f \n ",spp_a);
84  printf("\n                   Phase allociation series is
          %.f, %.f, %.f, %.f, %.f, %.f, %.f, %.f, %.f,
          slots are allocated respectively to R, Y, B, R, Y
          , B, R, Y, B....... phase in Sequence\n ",R_a,Y_a
          ,B_a,R1_a,R_a,Y_a,B_a,R1_a,R_a);
85  printf("\n                   By seeing Sequence its Slot
          per pole per phase is an Integer and such,
          balanced winding may be possible \n");
86  printf("\n  For Case (b) Slot per poles per phase  ,
          spp = %.3f \n ",spp_b);
```

```
87  printf(”\n                    Phase  allociation  series  is
        %.f , %.f , %.f \n”,R_b ,Y_b ,B_b ) ;
88  printf(”\n                    By  seeing  Sequence  its  Slot
        per  pole  per  phase  are  not  Integer  therefore  R−
        phase  will  have  8  slots  whereas  Y−phase  and  B−
        phase  will  have  12  slots  \n” ) ;
89  printf(”\n  For  Case  ( c )  Slot  per  poles  per  phase  ,
        spp  =  %.1 f  \n  ”,spp_c ) ;
90  printf(”\n                    Phase  allociation  series  is
        %.f , %.f , %.f , %.f , %.f , %.f , %.f , %.f , %.f , %.f
        , %.f , %.f  slots  are  allocated  respectively  to  R,
        Y,  B,  R,  Y,  B,  R,  Y,  B,  R,  Y,  B.......  phase  in
        Sequence\n  ”,R_c ,Y_c ,R_c ,Y_c ,R_c ,Y_c ,R_c ,Y_c ,R_c ,
        Y_c ,R_c ,Y_c ) ;
91  printf(”\n                    By  seeing  Sequence  its  Slot
        per  pole  per  phase  is  an  Integer  and  such ,
        balanced  winding  may  be  possible  \n” ) ;
```

Scilab code Exa 5.3 To find pitch factor

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  // First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  5  :  INDUCTION  MACHINES
8
9  // EXAMPLE  :  5.3
10
11 clear ; clc ; close ; // Clear  the  work  space  and
        console
12
13
14 // GIVEN  DATA
```

```
15
16  s = 24;                            // Total number of the
        pole
17  p = 4;                            // Total number of the
        poles in the Alternator
18
19
20  // CALCULATIONS
21  // For Case (a) Short pitching by one Slots
22
23  spp = s/p;                         // Slot per pole
24  E_a = ((180*2)/24)*(4/2);          // Slot angle in
        Electrical
25  kp_a = cosd(E_a/2);                // Pitch Factor
26  kp5_a = cosd((5*E_a)/2);           // Pitch Factor
27  kp7_a = cosd((7*E_a)/2);           // Pitch Factor
28
29  // For Case(b) Short pitching by two Slots
30
31  E_b = 2*((180*2)/24)*(4/2);        // Slot angle in
        Electrical
32  kp_b = cosd(E_b/2);                // Pitch Factor
33  kp5_b = cosd((5*E_b)/2)            // Pitch Factor
34  kp7_b = cosd((7*E_b)/2);           // Pitch Factor
35
36
37  // DISPLAY RESULTS
38
39  disp("EXAMPLE : 5.3 : SOLUTION :-") ;
40  printf("\n For Case (a) Short pitching by one Slots
        :- Pitch Facor , kp = %.4f \n ",kp_a);
41  printf("\n

        kp5 = %.4f \n ",kp5_a);
42  printf("\n

        kp7 = %.4f \n ",kp7_a);
43  printf("\n For Case (a) Short pitching by Two Slots
```

```
         :- Pitch Facor , kp = %.4 f \n ",kp_b);
44 printf(" \n

        kp5 = %.4 f \n ",kp5_b);
45 printf(" \n

        kp7 = %.4 f \n ",kp7_b);
```

Scilab code Exa 5.4 To find distribution factor

```
 1 // ELECTRICAL MACHINES
 2 // R.K.Srivastava
 3 // First Impression 2011
 4 // CENGAGE LEARNING INDIA PVT. LTD
 5
 6 // CHAPTER : 5 : INDUCTION MACHINES
 7
 8 // EXAMPLE : 5.4
 9
10 clear ; clc ; close ; // Clear the work space and
       console
11
12
13 // GIVEN DATA
14
15 s = 60;                           // Total number of Slot
16 m = 3;                            // Total number of Phase
17 p = 4;                            // Total number of Pole
18
19
20 // CALCULATIONS
21
22 M = s/(m*p);                                  // Slot
        per pole per Phase
23 sigma = 180/m;                                //
```

```
      Phase  Spread  in  angle  (deg)
24  Ka = sind((M*sigma)/2)/(M*sind(sigma/2));     //
      Distribution  Factor
25
26
27  // DISPLAY RESULTS
28
29  disp("EXAMPLE :  5.4  :  SOLUTION :−");
30  printf("\n (a) Distribution  Factor ,  Ka = %.1 f  \n",Ka
      )
```

Scilab code Exa 5.7 To find the synchronous speed

```
 1  // ELECTRICAL  MACHINES
 2  // R.K. Srivastava
 3  //  First  Impression  2011
 4  // CENGAGE LEARNING INDIA PVT.  LTD
 5
 6  // CHAPTER :  5  :  INDUCTION  MACHINES
 7
 8  // EXAMPLE :  5.7
 9
10  clear ; clc ; close ; // Clear  the  work  space  and
      console
11
12
13  // GIVEN DATA
14
15  f = 50;                          // Frequency  of  the  2−
      pole  Induction  Motor
16  p = 2;                           // Total  Number  of  Poles
17
18
19  // CALCULATIONS
20
```

```
21  Ns = (120*f)/p;                        // Synchronous Speed
        in RPM
22  Ns5 = -(120*f)/(5*p);            // Synchronous Speed
        of 5th order space harmonic in RPM
23  N5 = -(120*5*f)/p;                // Synchronous Speed
        of 5th order time harmonic in RPM
24  Ns7 = (120*f)/(7*p);             // Synchronous Speed
        of 7th order space harmonic in RPM
25  N7 = (120*7*f)/p;                   // Synchronous Speed
        of 7th order time harmonic in RPM
26
27
28  // DISPLAY RESULTS
29
30  disp("EXAMPLE : 5.7 : SOLUTION :-");
31  printf("\n (a.1) Synchronous Speed of 5th order
        space harmonic, Ns5 = %.f RPM \n",Ns5)
32  printf("\n (a.2) Synchronous Speed of 5th order time
         harmonic, N5 = %.f RPM \n",N5)
33  printf("\n (b.1) Synchronous Speed of 7th order
        space harmonic, Ns7 = %.2f RPM \n",Ns7)
34  printf("\n (b.2) Synchronous Speed of 7th order time
         harmonic, N7 = %.f RPM \n",N7)
```

Scilab code Exa 5.8 To find the frequency of the rotor current

```
1  // ELECTRICAL MACHINES
2  // R.K.Srivastava
3  // First Impression 2011
4  // CENGAGE LEARNING INDIA PVT. LTD
5
6  // CHAPTER : 5 : INDUCTION MACHINES
7
8  // EXAMPLE : 5.8
9
```

```scilab
10 clear ; clc ; close ; // Clear the work space and
      console
11
12
13 // GIVEN DATA
14
15 p_a = 6;                              // Total number of
      Poles in the Alternator
16 p_m = 4;                              // Total number of
      Poles of Induction Motor
17 N_a = 900;                           // Running Speed of
      the Alternator in RPM
18 N_m = 1250;                          // Running Speed of
      the Induction Motor in RPM
19 m = 3;                               // Total Number of
      phase in Induction Motor
20
21
22 // CALCULATIONS
23
24 f = (N_a*p_a)/120;                       // Frequency of
      the 6-pole Alternator running at 900 RPM in Hertz
25 Ns = (120*f)/p_m;                        // Synchronous
      Speed of 4-pole Induction Motor in RPM
26 s = (Ns-N_m)/Ns;                         // Slip
27 fr = s*f;                                // Frequency of
      the Rotor Current in Hertz
28
29
30 // DISPLAY RESULTS
31
32 disp("EXAMPLE : 5.8 : SOLUTION :-");
33 printf("\n (a) Frequency of the Rotor Current, fr =
    %.2f Hz \n",fr)
```

Scilab code Exa 5.9 To find the slip and frequency of rotor current

```scilab
1  // ELECTRICAL MACHINES
2  // R.K.Srivastava
3  // First Impression 2011
4  // CENGAGE LEARNING INDIA PVT. LTD
5
6  // CHAPTER : 5 : INDUCTION MACHINES
7
8  // EXAMPLE : 5.9
9
10 clear ; clc ; close ; // Clear the work space and
       console
11
12
13 // GIVEN DATA
14
15 p = 2;                            // Total number of
       Poles of Induction Motor
16 f = 50;                          // Frequency in Hertz
17 Nr = 2800;                       // Running Speed of
       the Induction Motor in RPM
18 m = 3;                           // Total Number of
       phase in Induction Motor
19 V = 400;                         // Operating Voltage
       of Induction Motor in Volts
20
21
22 // CALCULATIONS
23
24 Ns = (120*f)/p;                  // Synchronous
       Speed in RPM
25 s = 100*((Ns-Nr)/Ns);           // Slip in
       Percentage
26 fr = (s/100)*f;                  // Frequency of
       the Rotor Current in Hertz
27
28
```

```
29  // DISPLAY RESULTS
30
31  disp("EXAMPLE : 5.9 : SOLUTION :−");
32  printf("\n (a) Slip , s = %.2f percent \n",s);
33  printf("\n (b) Frequency of the Rotor Current , fr =
        %.2f Hz \n",fr)
```

Scilab code Exa 5.10 To find the rotor speed

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.10
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16
17  m = 3;                              // Total Number of
        phase in Induction Motor
18  p = 4;                              // Total number of
        Poles in Induction Motor
19  f = 50;                            // Frequency in
        Hertz
20  s = 0.03;                          // Slip
21
22
```

```
23  // CALCULATIONS
24
25  Ns = (120*f)/p;                          // Synchronous
        Speed in RPM
26  Nr = (1-s)*Ns;                           // Rotor Speed
        in RPM
27
28
29  // DISPLAY RESULTS
30
31  disp("EXAMPLE : 5.10 : SOLUTION :-");
32  printf("\n (a) Rotor Speed , Nr = %.f RPM \n",Nr)
```

Scilab code Exa 5.11 To find the speed of forward and backward rotating magnetic field with respect to stator and rotor

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.11
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16
17  m = 3;                                   // Total Number of
        phase in Induction Motor
```

```
18  p = 6;                              // Total number of
        Poles of Induction Motor
19  f = 50;                            // Frequency in
        Hertz
20  s = 0.03;                          // Slip
21
22
23  // CALCULATIONS
24
25  Ns = (120*f)/p;                    // Synchronous
        Speed in RPM
26  Nr = (1-s)*Ns;                     // Rotor Speed
        in RPM
27  Nf = Ns - Nr;                      // Speed of
        Forward Rotating magnetic fields with respect to
        stator and rotor in RPM
28  Nb = Ns + Nr;                      // Speed of
        Backward Rotating magnetic fields with respect to
         stator and rotor in RPM
29
30
31  // DISPLAY RESULTS
32
33  disp("EXAMPLE : 5.11 : SOLUTION :-");
34  printf("\n (a) Speed of Forward Rotating magnetic
        fields with respect to stator and rotor is equal
        to + %.f RPM \n",Nf)
35  printf("\n (b) Speed of Backward Rotating magnetic
        fields with respect to stator and rotor is equal
        to + %.f RPM \n",Nb)
```

Scilab code Exa 5.12 To find the speed of forward and backward rotating magnetic field with respect to stator and rotor

```
1
```

```
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.12
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 m = 3;                              // Total Number of
      phase in Induction Motor
17 p = 2;                              // Total number of
      Poles of Induction Motor
18 f = 50;                             // Frequency in
      Hertz
19 s = 0.05;                           // Slip
20
21
22 // CALCULATIONS
23
24 Ns = (120*f)/p;                         // Synchronous
      Speed in RPM
25 Nr = (1-s)*Ns;                          // Rotor Speed
      in RPM
26 Nf = s*Ns;                              // Speed of
      Forward Rotating magnetic fields with respect to
      stator and rotor in RPM
27 Nb = (p-s)*Ns;                          // Speed of
      Backward Rotating magnetic fields with respect to
       stator and rotor in RPM
28 fr = (p-s)*f;                           // Backward
      rotating magnetic field induces a current of
```

```
      frequency  in  Hertz
29
30
31  // DISPLAY RESULTS
32
33  disp("EXAMPLE :  5.12  :  SOLUTION :−");
34  printf("\n (a) Speed  of  Forward  Rotating  magnetic
        fields  with  respect  to  stator  and  rotor  is  equal
        to + %. f RPM \n",Nf)
35  printf("\n (b) Speed  of  Backward  Rotating  magnetic
        fields  with  respect  to  stator  and  rotor  is  equal
        to + %. f RPM \n",Nb)
```

Scilab code Exa 5.13 To find the speed of forward and backward rotating magnetic field with respect field to rotor to stator

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First  Impression  2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5  : INDUCTION MACHINES
8
9  // EXAMPLE :  5.13
10
11  clear ; clc ; close ; // Clear  the  work  space  and
        console
12
13
14  // GIVEN DATA
15
16
17  m = 3;                            // Total  Number  of
        phase  in  Induction  Motor
```

```scilab
18  p = 4;                                  // Total number of
        Poles of Induction Motor
19  f = 50;                                 // Frequency in
        Hertz
20  s = 0.05;                               // Slip
21
22
23  // CALCULATIONS
24
25  Ns = (120*f)/p;                         // Synchronous
        Speed in RPM
26  fr = s*f;                               // Rotor-induced
        Frequency of forward field in Hertz
27  Nfr = s*Ns;                             // Speed of
        Forward Rotating magnetic fields with respect to
        rotor surface in RPM
28  f2r = s*f;                              // Rotor-
        induced Frequency of Backward field in Hertz
29  Nbr = -(s*Ns);                          // Speed of
        Backward Rotating magnetic fields with respect to
        rotor surface in RPM
30  Nr = (1-s)*Ns;                          // Rotor
        running in Forward direction in RPM
31  Nfs = Nr+(s*Ns);                        // Speed of
        Forward Rotating magnetic fields with respect to
        stator surface in RPM
32  Nbs = Nr-(s*Ns);                        // Speed of
        Backward Rotating magnetic fields with respect to
        stator surface in RPM
33  Nbs_new = -(0.5*Ns)+(1-0.5)*Nr;         // Speed of
        Backward Rotating magnetic fields with respect to
        stator for 50% of slip in RPM
34
35
36  // DISPLAY RESULTS
37
38  disp("EXAMPLE : 5.13 : SOLUTION :-");
39  printf("\n (a.1) Speed of Forward Rotating magnetic
```

```
        fields with respect to rotor surface is equal to
        + %. f RPM \n",Nfr)
40  printf(”\n (a.2) Speed of Backward Rotating magnetic
            fields with respect to rotor surface is equal to
        + %. f RPM \n",Nbr)
41  printf(”\n (b.1) Speed of Forward Rotating magnetic
        fields with respect to stator surface is equal to
        + %. f RPM \n",Nfs)
42  printf(”\n (b.2) Speed of Backward Rotating magnetic
            fields with respect to stator surface is equal
        to + %. f RPM \n",Nbs)
43  printf(”\n  (c) Speed of Backward Rotating magnetic
            fields with respect to stator for 50 percenatge
        slip is equal to  %.1 f RPM \n",Nbs_new)
44  printf(”\n\n      [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n”
        );
45  printf(”\n         WRONGLY PRINTED ANSWERS ARE :− (a)
        Speed of Backward Rotating magnetic fields with
        respect to stator for 50 percenatge slip is equal
         to 0 RPM instead of %.1 f RPM  \n ”,Nbs_new);
```

Scilab code Exa 5.14 To find the speed of rotor

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.14
10
11  clear ; clc ; close ; // Clear the work space and
```

```
        console
12
13
14  // GIVEN DATA
15
16  f = 50;                    // Stator Frequency of Inductor
        Motor in Hertz
17  fr = 10;                   // Rotor Frequency of Inductor
        Motor in Hertz
18  p = 2;                     // Number of poles
19
20
21  // CALCULATIONS
22
23  Ns = (120*f)/p;       // Synchronous Speed of
        Induction Motor in RPM
24  s = fr/f;                  // Slip of the Induction Motor
25  Nr = (1-s)*Ns;        // Rotor Speed of the Induction
        Motor
26
27
28  // DISPLAY RESULTS
29
30  disp("EXAMPLE : 5.14 : SOLUTION :-");
31  printf("\n (a) Rotor Speed of Induction Motor, Nr =
        %.f RPM \n",Nr)
```

Scilab code Exa 5.15 To find equivalent circuit parameters current pf torque output power

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
```

```scilab
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.15
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 printf("\n EXAMPLE : 5.15 : \n\n           Given Data
       No-load test : 440V, 30A, 4.5KW \n");
17 printf("\n         Blocked rotor test :      90V,50
      Hz, 120A, 16KW \n");
18 m = 3;                          // Total Number of
      phase in Induction Motor
19 p = 6;                          // Total number of
      Poles of Induction Motor
20 V = 440;                        // Operating voltage
       of the Induction motor in Volts
21 out_hp = 100;                   // Output of the
      Induction motor in Horse-Power
22 R = 0.15;                       // Average dc
      Resistance in Ohms
23 Wsc = 16000;                    // Power at Blocked
      Rotor test in Watts
24 Vsc = 90;                       // Voltage at
      Blocked Rotor test in Volts
25 Isc = 120;                      // Current at
      Blocked Rotor test in Amphere
26 W0 = 4500;                      // Power at No-load
      test in Watts
27 V0 = 440;                       // Voltage at No-
      load test in Volts
28 I0 = 30;                        // Current at No-
      load test in Amphere
29 s = 0.05;                       // Slip
```

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```scilab
30  f = 50;                                    // Frequency in
        Hertz
31
32
33  // CALCULATIONS
34
35  R1 = R/2;                                  //
        DC winding Resistance per phase in Ohms
36  Rac = Wsc/(3*Isc^2);                       //
        AC Resistance referred to stator from locked
        rotor test at supply frequency in Ohms
37  R_2 = Rac - R1;                            //
        Per phase Rotor Resistance to Stator in Ohms
38  Zsc = Vsc/(sqrt(3)*Isc);                   //
        Per phase Impedance from locked rotor test in
        Ohms
39  Xs = sqrt((Zsc^2)-(Rac^2));                //
        Per phase leakage Reactance referred to stator in
         Ohms
40  theta_0 = acosd(W0/(V0*I0*sqrt(3)));       //
        No-load power factor angle in degree
41  Im = I0*sind(theta_0);                     //
        Reactive component of no-load current in Amphere
42  Xm = V0/(Im*sqrt(3));                      //
        Magnetizing Reactance in Ohms
43  Pc = W0 - 3*I0^2*R1;                       //
        Total Core loss in Watts
44  Rc = (V0/sqrt(3))^2*(3/Pc);                //
        Per phase core loss Resistance in Watts
45  Vph = V0/sqrt(3);                          //
        Per phase Voltage in Volts
46  Ic = Vph/Rc;                               //
        Core loss current in Amphere
47  I_m = Vph/(%i * Xm);                       //
        Magnetizing Current in Amphere
48  I_o = Ic + I_m;                            //
        No-load current in Amphere
49  I_2 = Vph/(R1+(R_2/s)+(%i*Xs));            //
```

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```scilab
                    Current  in  Amphere
50  I1 = I_o + I_2;                                    //
        Input  Current  in  Amphere
51  Pf = cosd(atand(imag(I1)/real(I1)));              //
        Power  factor
52  P1 = (3*(abs(I_2)^2*R_2)/s)/1000;                 //
        3−phase  air  gap  power  or  Rotor  intake  Power  in
        Kilo−Watts
53  Po = P1*(1-s);                                     //
        Output  Power  in  Kilo−Watts
54  Ws = 2*%pi*((120*f/p)*(1/60));                     //
        Angular  Roatation  in  Radians  per  Seconds
55  T = P1*1000/Ws;                                    //
        Torque  in  Newton−Meter

56

57

58  // DISPLAY RESULTS

59

60  disp(" SOLUTION :−");
61  printf("\n (a.1)  DC winding  Resistance  per  phase,
        R1 = %.3f  Ohms  \n",R1)
62  printf("\n (a.2)  AC  Resistance  referred  to  stator
        from  locked  rotor  test  at  supply  frequency  = %.4
        f  Ohms  \n",Rac)
63  printf("\n (a.3)  Per  phase  Rotor  Resistance  to
        Stator,  R2 = %.4f  Ohms  \n",R_2)
64  printf("\n (a.4)  Per  phase  Impedance  from  locked
        rotor  test,Zsc = %.3f  Ohms  \n",Zsc)
65  printf("\n (a.5)  Per  phase  leakage  Reactance
        referred  to  stator,  Xs = %.4f  Ohms  \n",Xs)
66  printf("\n (a.6)  No−load  power  factor  angle,
        theta_O = %.2f  Degree  \n",theta_0)
67  printf("\n (a.7)  Reactive  component  of  no−load
        current,  Im = %.1f  A  \n",Im)
68  printf("\n (a.8)  Magnetizing  Reactance,  Xm = %.2f
        Ohms  \n",Xm)
69  printf("\n (a.9)  Total  Core  loss,  Pc = %.1f  W  \n",
        Pc)
```

```
70  printf("\n (a.10) Per phase core loss Resistance, Pc
        = %.f Ohms \n",Rc)
71  printf("\n (a.11) Per phase Voltage, Vph = %.f V \n"
        ,Vph)
72  printf("\n (a.12) Core loss current, Ic = %.2f < %.f
        A \n",abs(Ic),atand(imag(Ic),real(Ic)))
73  printf("\n (a.13) Magnetizing Current, Im = %.1f < %
        .f A \n",abs(I_m),atand(imag(I_m),real(I_m)))
74  printf("\n (a.14) No-load current, I0 = %.2f < %.2f
        A \n",abs(I_o),atand(imag(I_o),real(I_o)))
75  printf("\n (a.15) Current, I2 = %.2f < %.2f A \n",
        abs(I_2),atand(imag(I_2),real(I_2)))
76  printf("\n    (b)  Input current, I1 = %.2f < %.2f A
        \n",abs(I1),atand(imag(I1),real(I1)))
77  printf("\n    (c)  Power Factor, Pf = %.4f Lagging \n
        ",Pf)
78  printf("\n    (d)  Output Power, P0 = %.1f kW \n",Po)
79  printf("\n    (e)  Torque, T = %.2f NM \n",T)
```

Scilab code Exa 5.17 To find per phase core loss resistance and magnetizing reactance of equivalent circuit

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.17
10
11 clear ; clc ; close ; // Clear the work space and
        console
12
```

```
13
14  // GIVEN DATA
15
16  printf("\n EXAMPLE : 5.17 : \n\n            Given Data
       No−load  test  :  440V,  3.0A,  500KW,  50Hz  \n");
17  printf("\n         Blocked  rotor  test  at  rated
       frequency  :  110V,  18A,  2500W,  50Hz  \n");
18  printf("\n          DC  test  on  Stator  per  phase  :  10
       V,  15A  \n");
19  m = 3;                          //  Total  Number  of
       phase  in  Induction  Motor
20  p = 4;                          //  Total  number  of
       Poles  of  Induction  Motor
21  f = 50;                         //  Frequency  in
       Hertz
22  V = 440;                        //  Operating  Voltage
       of  the  Inductuon  Motor
23  out_hp = 20;                    //  Motor  Power
       Rating  in  Horse−Power
24  Vdc = 10;                       //  DC  Voltage  in
       Volts
25  Idc = 15;                       //  DC  Current  in
       Amphere
26  Wsc = 2500;                     //  Power  at  Blocked
       Rotor  test  rated  frequency  in  Watts
27  Wsc_red = 2050;                 //  Power  at  Blocked
       Rotor  test  reduced  frequency  in  Watts
28  Vsc = 110;                      //  Voltage  at
       Blocked  Rotor  test  rated  frequency  in  Volts
29  Isc = 18;                       //  Current  at
       Blocked  Rotor  test  rated  frequency  in  Amphere
30  Wo = 500;                       //  Power  at  No−load
       test  in  Watts
31  Vo = 440;                       //  Voltage  at  No−
       load  test  in  Volts
32  Io = 4.0;                       //  Current  at  No−
       load  test  in  Amphere
33  fsc = 50;                       //  Rated  Frequency
```

```scilab
                      at blocked rotor test in Hertz
34  fo = 50;                                // Rated Frequency
       at no-load test in Hertz
35  fsc1 = 15;                              // Reduced Frequency
        at blocked rotor in Hertz
36  Pfw = 200;                              // Friction and
       Windage loss in Watts
37
38
39  // CALCULATIONS
40
41  R1dc = Vdc/Idc;                         // DC
       winding Resistance per phase in Ohms
42  Rac = Wsc/(3*Isc^2);                    // AC
       Resistance from Locked rotor test at supply
       frequency
43  Rac_red = Wsc_red/(3*Isc^2);            // AC
       Resistance from Locked rotor test at reduced
       frequency
44  R1ac = (Rac/Rac_red)*R1dc;              // Corrected
        Value of AC stator winding Resistance in Ohms
45  R2dc = Rac_red - R1dc;                  // Second
       rotor parameter, rotor resistance referred to
       stator is at low frequency in Ohms
46  Zsc = Vsc/(sqrt(3)*Isc);                //
       Per phase Impedance from locked rotor test at
       power frequency in Ohms
47  Xs = sqrt((Zsc^2)-(Rac^2));             //
       Per phase leakage Reactance referred to stator in
        Ohms
48  theta_0 = acosd(Wo/(Vo*Io*sqrt(3)));    //
       No-load power factor angle in degree
49  Im = Io*sind(theta_0);                  //
       Reactive component of no-load current in Amphere
50  Xm = Vo/(Im*sqrt(3));                   //
       Magnetizing Reactance in Ohms
51  Pc = Wo - 3*Io^2*R1ac-Pfw;              //
       Total Core loss in Watts
```

```
52  Rc = (Vo/sqrt(3))^2*(3/Pc);                    //
        Per phase core loss Resistance in Watts
53
54
55  // DISPLAY RESULTS
56
57  disp(" SOLUTION :-");
58  printf("\n (a)   Magnetizing Reactance of Equivalent
        circuit , Xm = %.1f Ohms \n",Xm)
59  printf("\n (b) Per phase core loss Resistance , Pc =
        %.f Ohms \n",Rc)
```

Scilab code Exa 5.18 To find current pf torque output power

```
1
2   // ELECTRICAL MACHINES
3   // R.K. Srivastava
4   // First Impression 2011
5   // CENGAGE LEARNING INDIA PVT. LTD
6
7   // CHAPTER : 5 : INDUCTION MACHINES
8
9   // EXAMPLE : 5.18
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15  // From Previous problem data (Example 5.17)
16
17  R1ac = 0.8127;                      // Corrected Value
        of AC stator winding Resistance in Ohms
18  R2dc = 1.4433;                      // Second rotor
        parameter , rotor resistance referred to stator is
```

```
           at  low  frequency  in  Ohms
19  Xs = 2.42;                          // Per  phase  leakage
       Reactance  referred  to  stator  in  Ohms
20  Xm = 64.4;                          // Magnetizing
       Reactance  in  Ohms
21  Rc = 742;                           // Per  phase  core
       loss  Resistance  in  Watts
22  s = 0.035;                          // Slip
23  m = 3;                              // Total  Number  of
       phase  in  Induction  Motor
24  p = 4;                              // Total  number  of
       Poles  of  Induction  Motor
25  f = 50;                             // Frequency  in  Hertz
26  V = 440;                            // Operating  Voltage
       of  the  Inductuon  Motor
27  out_hp = 20;                        // Motor  Power  Rating
        in  Horse−Power
28
29
30  // CALCULATIONS
31
32  Vph = V/sqrt(3);                           //
       Per  phase  Voltage  in  Volts
33  Ic = Vph/Rc;                               //
       Core  loss  current  in  Amphere
34  I_m = Vph/(%i * Xm);                       //
       Magnetizing  Current  in  Amphere
35  I_o = Ic + I_m;                            //
       No−load  current  in  Amphere
36  I_2 = Vph/(R1ac+(R2dc/s)+(%i*Xs));         //
       Current  in  Amphere
37  I1 = I_o + I_2;                            //
       Input  Current  in  Amphere
38  Pf = cosd(atand(imag(I1)/real(I1)));       //
       Power  factor
39  P1 = 3*(abs(I_2)^2*R2dc)/s;                  // 3−
       phase  air  gap  power  or  Rotor  intake  Power  in
       Watts
```

```
40 Po = P1*(1-s);                           //
       Output Power in Watts
41 Ws = 2*%pi*((120*f/p)*(1/60));           //
       Angular Roatation in Radians per Seconds
42 T = P1/Ws;                               //
       Torque in Newton−Meter
43
44
45 // DISPLAY RESULTS
46
47 disp("EXAMPLE : 5.18 : SOLUTION :−");
48 printf("\n    (a)   Input current , I1 = %.2f < %.2f A
       \n",abs(I1),atand(imag(I1),real(I1)))
49 printf("\n    (b)   Power Factor , Pf = %.3f Lagging \n
       ",Pf)
50 printf("\n    (c)   Output Power , P0 = %.2f W \n",Po)
51 printf("\n    (d)   Torque , T = %.2f NM \n",T)
52 printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
       WRONGLY ( I verified by manual calculation )]\n"
       );
53 printf("\n      WRONGLY PRINTED ANSWERS ARE :− (a) T
       = 4340.82 Nm instead of %.2f Nm \n ",T);
54 printf("\n\n        IN TEXT BOOK, CALCULATION OF
       TORQUE IS NOT DONE \n ");
```

Scilab code Exa 5.19 To find input line current pf torque Hp output and efficiency

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 5 : INDUCTION MACHINES
```

```
8
9  // EXAMPLE : 5.19
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 s = 0.05;                          // Slip
17 m = 3;                             // Total Number of
       phase in Induction Motor
18 p = 4;                            // Total number of
       Poles of Induction Motor
19 f = 50;                           // Frequency in
       Hertz
20 V = 440;                          // Operrating
       Voltage of the Inductuon Motor
21 R1 = 0.10;                        // Circuit Parameter
        in Ohms
22 R2 = 0.11;                        // Circuit Parameter
        in Ohms
23 X1 = 0.35;                        // Circuit Parameter
        in Ohms
24 X2 = 0.40;                        // Circuit Parameter
        in Ohms
25 pf = 0.2;                         // Power factor (
       Lagging )
26 Pr = 900;                         // Rotational Loss
       in Watts
27 Psc = 1000;                       // Stator core loss
       in Watts
28 I = 15;                           // Line current
     draws by the motor in Amphere
29
30
31 // CALCULATIONS
32
```

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```
33  Vph = V/sqrt(3);
        // Per phase Voltage in Volts
34  I_2 = Vph/(R1+(R2/s)+(%i*(X1+X2)));
        // Current in Amphere
35  Io = I * exp(-( %i * acosd(pf) * %pi/180));
        // No-load current in Amphere
36  I1 = Io + I_2;
        // Input line Current in Amphere
37  PF = cosd(atand(imag(I1)/real(I1)));
        // Power factor
38  Ws = 2*%pi*((120*f/p)*(1/60));
        // Angular Roatation in Radians per Seconds
39  Pg = (3*(abs(I1)^2*R2))/s;
        // 3-phase air gap power or Rotor intake Power in
         Watts
40  T = Pg/Ws;
        // Torque in Newton-Meter
41  Po = Pg*(1-s)-Pr;
        // Output Power in Watts
42  Po_HP = Po/746;
        // Output Power in Horse-Power
43  eta = (Po/(Po+Psc+Pr))*100;
        // Efficiency in Percentage
44
45
46  // DISPLAY RESULTS
47
48  disp("EXAMPLE : 5.19 : SOLUTION :-");
49  printf("\n    (a)  Input line current, I1 = %.1f < %
        .2f A \n",abs(I1),atand(imag(I1),real(I1)))
50  printf("\n    (b)  Power Factor, Pf = %.4f Lagging \n
        ",PF)
51  printf("\n    (c)  Output Power, P0 = %.1f HP \n",
        Po_HP)
52  printf("\n    (d)  Torque, T = %.2f Nm \n",T)
53  printf("\n    (e)  Efficiency, eta = %.1f Percenatge
        \n",eta)
54  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
```

```
        WRONGLY ( I verified by manual calculation )]\n"
        ) ;
55  printf (" \n          WRONGLY PRINTED ANSWERS ARE :− (a)
        I1 = 114.2 < −24.68 A instead of %.1 f<%.2 f A \n ",
        abs (I1) , atand (imag (I1) , real (I1) ) ) ;
56  printf (" \n                                    (b) T
        = 548.24 Nm instead of %.2 f Nm \n ",T) ;
57  printf (" \n                                    (c)
        Po = 108.4 HP instead of %.1 f HP \n ",Po_HP) ;
```

Scilab code Exa 5.20 To find input line current pf torque Hp output efficiency

```
1
2   // ELECTRICAL MACHINES
3   // R.K. Srivastava
4   // First Impression 2011
5   // CENGAGE LEARNING INDIA PVT. LTD
6
7   // CHAPTER : 5 : INDUCTION MACHINES
8
9   // EXAMPLE : 5.20
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  m = 3;                              // Total Number of
        phase in Induction Motor
17  p = 6;                              // Total number of
        Poles of Induction Motor
18  f = 50;                            // Frequency in Hertz
19  V = 440;                           // Operating Voltage
```

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```scilab
        of the Inductuon Motor
20  R1 = 0.25;                          // Circuit Parameter
        in Ohms
21  R2 = 0.25;                          // Circuit Parameter
        in Ohms
22  X1 = 0.75;                          // Circuit Parameter
        in Ohms
23  X2 = 0.75;                          // Circuit Parameter
        in Ohms
24  Xm = 1000;                          // Circuit Parameters
         in Ohms
25  Rc = 100;                           // Circuit Parameters
         in Watts
26  s = 0.025;                          // Slip
27  Pr = 450;                           // Rotational Loss in
        Watts
28  Psc = 800;                          // Stator core loss
        in Watts
29
30
31  // CALCULATIONS
32
33  Vph = V/sqrt(3);
        // Per phase Voltage in Volts
34  I_2 = Vph/(R1+(R2/s)+(%i*(X1+X2)));
        // Current in Amphere
35  Ic = Vph/Rc;                                            //
        Core loss current in Amphere
36  I_m = Vph/(%i * Xm);                                    //
        Magnetizing Current in Amphere
37  I_o = Ic + I_m;                                         //
        No-load current in Amphere
38  I1 = I_o + I_2;                                         //
        Input Current in Amphere
39  Pf = cosd(atand(imag(I1)/real(I1)));                    //
        Power factor
40  Ns = (120*f)/p;                                         //
        Synronous Speed in RPM
```

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```scilab
41  Pg = 3*(abs(I_2)^2*R2)/s;                          //
       3-phase air gap power or Rotor intake Power in
       Watts
42  Pm = Pg*(1-s);                                     //
       Output Power in Watts
43  Ws = 2*%pi*Ns*(1/60);                              //
       Angular Roatation in Radians per Seconds
44  T = Pg/Ws;                                         //
       Torque in Newton-Meter
45  Po = Pm-Pr;                                        //
       Output Power in Watts
46  Po_HP = Po/746;                                    //
       Output Power in Horse-Power
47  eta = (Po/(Po+Psc+Pr))*100;                        //
       Efficiency in Percentage
48
49
50  // DISPLAY RESULTS
51
52  disp("EXAMPLE : 5.20 : SOLUTION :-");
53  printf("\n    (a)  Input line current, I1 = %.f < %.2
       f A \n",abs(I1),atand(imag(I1),real(I1)))
54  printf("\n    (b)  Power Factor, Pf = %.4f Lagging \n
       ",Pf)
55  printf("\n    (c)  Output Power, P0 = %.2f HP \n",
       Po_HP)
56  printf("\n    (d)  Torque, T = %.1f Nm \n",T)
57  printf("\n    (e)  Efficiency, eta = %.1f Percenatge
       \n",eta)
58  printf("\n\n    [ TEXT BOOK SOLUTION IS PRINTED
       WRONGLY ( I verified by manual calculation )]\n"
       );
59  printf("\n        WRONGLY PRINTED ANSWERS ARE :- (a)
       I1 = 26.8-j3.584 {27<-7.62} A in instead of (%.1f
       )+(j%.3f) {%.f<%.2f} A \n ",real(I1),imag(I1),abs
       (I1),atand(imag(I1),real(I1)));
60  printf("\n                                      (b)
       pf = 0.9885 Lagging instead of %.4f Lagging \n ",
```

```
        Pf ) ;
```

Scilab code Exa 5.21 To find torque and output power

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  //  First  Impression  2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.21
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 m = 3;                          // Total Number of
       phase in Induction Motor
17 p = 4;                          // Total number of
       Poles of Induction Motor
18 s = 0.05;                       // Slip
19 f = 50;                         // Frequency in
       Hertz
20 Tm = 500;                       // Maximum Torque in
        Newton−Meter
21 Tst = 200;                      // Starting Torque
       in Newton−Meter
22 sst = 1.0;                      // Starting Slip
23
24
25 // CALCULATONS
```

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```
26
27  p1 = poly([1 -5 1],'sm','c');      // Slip at Maximum
       Torque (obtained from Equation  Tst = (2*Tm)/((
       sst/sm)+(sm+sst))
28  a = roots(p1);                     // Value of slip at
       Maximum Torque (obtained from Equation  Tst = (2*
       Tm)/((sst/sm)+(sm+sst))
29  sm = a(2,1);                       // Slip at Maximum
       Torque (obtained from Equation  Tst = (2*Tm)/((
       sst/sm)+(sm+sst)) { 1st root is 4.8 so its out of
        range because slip value is lies between 0−1 so
       its neglected and second root will be slip }
30  T = (2*Tm)/((s/sm)+(sm/s));        // Torque at 0.05
       slip
31  Ns = (120*f)/p;                    // Synchronous Speed
        in RPM
32  Wr = (2*%pi)*(1-s)*(Ns/60);        // Angular Velocity
       in Radians−per−Second
33  P = T * Wr;                        // Power Output in
       Watts
34  P_HP = P/746;                      // Power Output in
       Horse−Power
35
36
37  // DISPLAY RESULTS
38
39  disp("EXAMPLE : 5.21 : SOLUTION :−");
40  printf("\n (a) Torque at 0.05 slip , T = %.2f Nm \n",
       T)
41  printf("\n (b) Power Output at 0.05 slip , P = %.1f W
        = %.2f HP \n",P,P_HP)
```

Scilab code Exa 5.22 To find current pf and torque

```
1
```

```
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.22
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 Wsc = 1000;                        // Power at Blocked
      Rotor test in Watts
17 Vsc = 56;                          // Voltage at Blocked
       Rotor test in Volts
18 Isc = 18;                          // Current at Blocked
       Rotor test in Amphere
19 Woc = 52;                          // Power at No-load
      test in Watts
20 Voc = 220;                         // Voltage at No-load
       test in Volts
21 Ioc = 2.6;                         // Current at No-load
      test in Amphere
22 m = 3;                             // Total Number of
      phase in Induction Motor
23 p = 4;                             // Total number of
      Poles of Induction Motor
24 V = 220;                           // Operating voltage
      of the Induction motor in Volts
25 f = 50;                            // Frequency in Hertz
26 s = 0.05;                          // Slip
27 R = 0.65;                          // Per phase stator
      Resistance in Ohms
28
```

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```scilab
29
30  // CALCULATIONS
31
32  Vph = Voc/sqrt(3);                                  //
        Per phase Voltage in Volts
33  Wo = Woc/m;                                         //
        Per phase No-load loss in Watts
34  theta_0 = acosd(Wo/(Voc*Ioc*sqrt(3)));             //
        No-load power factor angle in degree
35  VSC = Vsc/sqrt(3);                                 //
        Per phase locked rotor Voltage in Volts
36  WSC = Wsc/m;                                        //
        Per phase locked rotor loss in Watts
37  theta_sc = acosd(WSC/(VSC*Isc));                   //
        No-load power factor angle in degree
38  ISC = Isc*(Voc/Vsc);                               //
        locked rotor current at full Voltage in Amphere
39  Re = WSC/Isc^2;                                     //
        Resistance in Ohms
40  R1 = R*1.1;                                         //
        Per phase AC stator Resistance in Ohms
41  R_2 = Re - R1;                                      //
        Per phase rotor Resistance in Ohms
42  Zsc = VSC/Isc;                                      //
        Per phase impedance in Ohms
43  Xs = sqrt((Zsc^2)-(Re^2));                          //
        Leakage Reactance in Ohms
44  I_2 = (Voc/sqrt(3))/sqrt((R1+(R_2/s))^2+(Xs^2));  //
        Current in Amphere
45  pf = cosd(atand(Xs/(R1+(R_2/s))));                 //
        Power Factor
46  Ws = 2*%pi*((120*f/p)*(1/60));                     //
        Rotational Speed in Radians per Seconds
47  Pg = (3*(abs(I_2)^2*R_2))/s;                       //
        3-phase air gap power or Rotor intake Power in
        Watts
48  T = Pg/Ws;                                          //
        Torque in Newton-Meter
```

```
49  // CALCULATIONS OR DATA OBTAINED FROM CIRCLE DIAGRAM
        FIGURE 5.35 and PAGE NO:−303
50  OA = 2.60;                                           //
        Correspounding Current in Amphere at 87' from Y−
        axis (from Circle diagram)
51  OE = 70.70;                                          //
        Correspounding Current in Amphere at 55' from Y−
        axis (from Circle diagram)
52  OP = 17.77;                                          //
        Current in Amphere (from Circle diagram)
53  OV = Voc/sqrt(3);                                    //
        Phase Voltage in No−load test or value obatined
        from circle diagram in Volts
54  PK = 11.6;                                           //
        Correspounding Value from Circle diagram
55  JK = 0.8;                                            //
        Correspounding Value from Circle diagram
56  PJ = 10.8;                                           //
        Correspounding Value from Circle diagram
57  PM = 11.6;                                           //
        Correspounding Value from Circle diagram
58  Pir = 3*OV*PK;                                       //
        Total Rotor intake in Watts
59  Plr = 3*OV*JK;                                       //
        Total Rotor loss in Watts
60  Po = 3*OV*PJ;                                        //
        Total Mechanical power output in Watts
61  T_c = (3*OV*PK)/Ws;                                  //
        Total Torque in Newton−Meter
62  s_c = JK/PK;                                         //
        Slip obtained from Circle diagram
63  s_pc = 100*s_c;                                      //
        Slip in percentage
64  eta = 100*(PJ/PM);                                   //
        Eifficiency in Percentage
65
66
67  // DISPLAY RESULTS
```

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```
68
69  disp("EXAMPLE : 5.22 : SOLUTION :−");
70  printf("\n    (a)  Input line current, I2 = %.2f A \n
        ",I_2)
71  printf("\n    (b)  Power Factor, Pf = %.3f \n",pf)
72  printf("\n    (c)  Torque, T = %.2f Nm \n",T)
73  printf(" \n Verification Results from Circle Diagram
        :−\n");
74  printf("\n    (a)  Efficency, eta = %.2f Percent \n",
        eta)
75  printf("\n    (b)  slip, s = %.3f = %.f percent \n",
        s_c,s_pc)
76  printf("\n    (c)  Torque, T = %.2f Nm \n",T_c)
```

Scilab code Exa 5.23 To find initial starting current and torque in each cases

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.23
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  R1 = 0.2;                        // Circuit Parameter
        in Ohms
```

```
17  R2 = 0.4;                              // Circuit Parameter
        in Ohms
18  X1 = 1.0;                              // Circuit Parameter
        in Ohms
19  X2 = 1.5;                              // Circuit Parameter
        in Ohms
20  m = 3;                                  // Total Number of
        phase in Induction Motor
21  p = 2;                                  // Total number of
        Poles of Induction Motor
22  f = 50;                                 // Frequency in
        Hertz
23  V = 440;                                // Operating Voltage
         of the Inductuon Motor
24
25
26  // CALCULATIONS
27
28  Ws = 2*%pi*f;                             //
        Synchronous angular speed in Radians per second
29  Z = (R1+R2)+((%i)*(X1+X2));                   // At
        slip s=1, the impedance seen from the terminals
        in Ohms
30  s = 1;                                   // Slip
31
32  // For Case(a) Winding is connected in star
33
34  Isy_a = V/(abs(Z)*sqrt(3));                //
        Current in Amphere
35  Tsy_a = (3*Isy_a^2*R2)/(s*Ws);             //
        Torque in Newton-Meter
36
37  // Winding is connected in delta
38
39  Isd_a = (V*sqrt(3))/abs(Z);                //
        Current in Amphere
40  Tsd_a = (3*(Isd_a/sqrt(3))^2*R2)/(s*Ws);      //
        Torque in Newton-Meter
```

```
41  I_R = Isd_a/Isy_a;                                    //
        Ratio of the line current
42  T_R = Tsd_a/Tsy_a;                                    //
        Ratio of the Torque
43
44  // For Case(b) Machine is started using auto-
        transfromer and voltage is 50% reduced
45
46  Isy_b = (0.5*V)/(abs(Z)*sqrt(3));                     //
        Current in Amphere when Winding is connected
        star
47  Tsy_b = (3*Isy_b^2*R2)/(s*Ws);                        //
        Torque in Newton-Meter when Winding is connected
        star
48  Isd_b = (0.5*V*sqrt(3))/abs(Z);                       //
        Current in Amphere when Winding is connected
        delta
49  Tsd_b = (3*(Isd_b/sqrt(3))^2*R2)/(s*Ws);             //
        Torque in Newton-Meter when Winding is connected
        delta
50
51  // For Case(c) Both Voltage and Frequency are
        reduced to 50%
52
53  f_new = (10/100)*f;                                   //
        New Frequency
54  Ws_c = 2*%pi*f_new;                                   //
        Synchronous angular speed in Radians per second
55  Z_c = ((R1+R2)+((%i)*(X1+X2))*(f_new/f));            //
        At slip s=1, the impedance seen from the
        terminals in Ohms
56  Isy_c = (0.1*V)/(abs(Z_c)*sqrt(3));                   //
        Current in Amphere when Winding is connected
        star
57  Tsy_c = (3*Isy_c^2*R2)/(s*Ws_c);                      //
        Torque in Newton-Meter when Winding is connected
        star
58  Isd_c = (0.1*V*sqrt(3))/abs(Z_c);                     //
```

```scilab
         Current in Amphere when Winding is connected
         delta
59   Tsd_c = (3*(Isd_c/sqrt(3))^2*R2)/(s*Ws_c);          //
         Torque in Newton−Meter when Winding is connected
         delta
60
61
62   // DISPLAY RESULTS
63
64   disp("EXAMPLE : 5.23 : SOLUTION :−");
65   printf("\n For Case (a.1) Winding is connected in
         star \n");
66   printf("\n (a.1.1) Per phase impedance seen from the
         terminals in Ohms, Z = %.3f < %.1f Ohms \n",abs(
         Z),atand(imag(Z),real(Z)));
67   printf("\n (a.1.2) Initial Starting Current , Isy =
         %.2f A \n",Isy_a)
68   printf("\n (a.1.3) Starting Torque , Tsy = %.1f Nm \
         n",Tsy_a)
69   printf("\n For Case (a.2) Winding is connected in
         delta \n" );
70   printf("\n (a.2.1) Initial Starting Current , Isd =
         %.2f A \n",Isd_a)
71   printf("\n (a.2.2) Starting Torque , Tsd = %.2f Nm \
         n",Tsd_a)
72   printf("\n For Case (b) Machine is started using
         auto−transfromer and voltage is 50 percentage
         reduced :− (b.1) Winding is connected in star \n
         ")
73   printf("\n (b.1.1) Per phase impedance seen from the
         terminals in Ohms, Z = %.3f<%.1f Ohms \n",abs(Z)
         ,atand(imag(Z),real(Z)));
74   printf("\n (b.1.2) Initial Starting Current , Isy =
         %.1f A \n",Isy_b)
75   printf("\n (b.1.3) Starting Torque , Tsy = %.2f Nm \
         n",Tsy_b)
76   printf("\n For Case (b.2) Winding is connected in
         delta \n" );
```

```
77  printf("\n (b.2.1) Initial Starting Current , Isd =
        %.2f A \n",Isd_b)
78  printf("\n (b.2.2) Starting Torque , Tsd = %.f Nm \n
        ",Tsd_b)
79  printf("\n For Case (c) Both Voltage and Frequency
        are reduced to 50 percentage :- (c.1) Winding is
        connected in star \n ");
80  printf("\n (c.1.1) Per phase impedance seen from the
        terminals in Ohms, Z = %.2f<%.2f Ohms \n",abs(
        Z_c),atand(imag(Z_c),real(Z_c)));
81  printf("\n (c.1.2) Initial Starting Current , Isy =
        %.2f A \n",Isy_c)
82  printf("\n (c.1.3) Starting Torque , Tsy = %.2f Nm \
        n",Tsy_c)
83  printf("\n For Case (c.2) Winding is connected in
        delta \n" );
84  printf("\n (c.2.1) Initial Starting Current , Isd =
        %.2f A \n",Isd_c)
85  printf("\n (c.2.2) Starting Torque , Tsd = %.2f Nm \
        n",Tsd_c)
86  printf('\nComparing the Calculated values of
        starting current and torque eid rated frequency
        and rated voltage\n")
87  printf("\n                          star
                              delta\n")
88  printf("\n                    440V,50Hz    44V,5Hz
                 440V,50Hz    44V,5Hz \n")
89  printf("\n starting current    %.2f A     %.f A
                 %.f A        %.2f A \n",Isy_a,Isy_c,
        Isd_a,Isd_c)
90  printf("\n starting Torque      %.1f Nm   %.2f Nm
                 %.f Nm       %.2f Nm \n",Tsy_a,Tsy_c,
        Tsd_a,Tsd_c)
91  printf("\n\n    [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
92  printf("\n        WRONGLY PRINTED ANSWERS ARE :- For
        Case (a.2) Winding is connected in delta :- (a)
```

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```
        Initial  Starting  Current  Isy = 254.01 A instead
        of %.2f A \n\n ",Isd_a);
```

Scilab code Exa 5.24 To find initial starting current during DOL starting

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.24
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 m = 3;                          // Total Number of
       phase in Induction Motor
17 f = 50;                         // Frequency in
       Hertz
18 V = 440;                        // Operating voltage
        of the Induction Motor in Volts
19 R1 = 0.2;                       // Circuit Parameter
       in Ohms
20 R2 = 0.4;                       // Circuit Parameter
       in Ohms
21 X1 = 1.0;                       // Circuit Parameter
       in Ohms
22 X2 = 1.5;                       // Circuit Parameter
       in Ohms
```

```
23  Rc = 150;                              // Circuit Parameter
        in Ohms
24  Xm = 30;                               // Circuit Parameter
        in Ohms
25
26
27  // CALCULATIONS
28
29  V1 = V/sqrt(3);
        // Rated Voltage in Volts
30  Zdol = (R1+%i*X1)+(Rc*%i*Xm*(R2+%i*X2))/(Rc*%i*Xm+Rc
        *(R2+%i*X2)+(%i*Xm)*(R2+%i*X2));
                                                        //
        Equivalent impedance per phase in DOL starter in
        Ohms
31  I = V1/Zdol;
        // Starting Current in DOL starter in Amphere
32
33  // For Case(a) A per Phase resistance of 0.5 Ohms is
         added in Series with the stator circuit
34
35  Zsr =   (0.5+R1+%i*X1)+((Rc*%i*Xm*(R2+%i*X2))/((Rc*%i
        *Xm+Rc*(R2+%i*X2)+(%i*Xm)*(R2+%i*X2))));
                                                // Total
        impedance seen from the terminals in Ohms
36  Isr = V1/Zsr;
                                                        //
        Starting Current in DOL starter in Amphere
37
38  // For Case(b) A per Phase resistance of 0.5 Ohms is
         added in Series with the rotor circuit here
        assumed that stator to rotor turn ratio is 1.0
39
40  Zrr =   (R1+%i*X1)+((Rc*%i*Xm*(0.5+R2+%i*X2))/(Rc*%i*
        Xm+Rc*(0.5+R2+%i*X2)+(%i*Xm)*(0.5+R2+%i*X2)));
                                        // Total impedance
        seen from the terminals in Ohms
41  Irr = V1/Zrr;
```

```
         // Starting Current in DOL starter in Amphere
42
43 // For Case(c) When applied Voltage reduced to 50%
44
45 I_c = (0.5*V1)/Zdol;
         // Starting Current in DOL starter in Amphere
46
47 // For Case(d) When Motor is supplied by reduced
       Voltage of 44V ( Voltage is reduced by 10%) and
       the reduced frequency is 5Hz
48
49 f_n = 5;                                            //
       Reduced Frequency in Hertz
50 X1_n = (f_n/f)*X1;                                  //
       Changed Circuit Parameter in Ohms
51 X2_n = (f_n/f)*X2;                                  //
       Changed Circuit Parameter in Ohms
52 Xm_n = (f_n/f)*Xm;                                  //
       Changed Circuit Parameter in Ohms
53 Zdol_n = (R1+%i*X1_n)+((Rc*%i*Xm_n*(R2+%i*X2_n))/(Rc
     *%i*Xm_n+Rc*(R2+%i*X2_n)+(%i*Xm_n)*(R2+%i*X2_n)))
     ;                              // Equivalent impedance
       per phase in DOL starter in Ohms
54 I_n = (V1*0.1)/Zdol_n;                              //
       Starting Current in DOL starter in Amphere
55 Ratio = abs(I_n)/abs(I);                            //
       Ratio of the Starting Current witha the rated
       Voltage and frequency to the reduced Voltage and
       frequency
56
57
58 // DISPLAY RESULTS
59
60 disp("EXAMPLE : 5.24 : SOLUTION :-");
61 printf("\n Normal Initial Starting Current in DOL
       starter, I = %.1f <%.1f A \n",abs(I),atand(imag(I
       ),real(I)))
62 printf("\n For Case(a) A per Phase resistance of 0.5
```

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```
        Ohms is added in Series with the stator circuit
        \n")
63  printf("\n                    Initial Starting Current in
        DOL starter, I = %.1f <%.2f A \n",abs(Isr),atand(
        imag(Isr),real(Isr)))
64  printf("\n  For Case(b) A per Phase resistance of
        0.5 Ohms is added in Series with the rotor
        circuit \n")
65  printf("\n                    Initial Starting Current in
        DOL starter, I = %.2f <%.1f A \n",abs(Irr),atand(
        imag(Irr),real(Irr)))
66  printf("\n  For Case(c) When applied Voltage reduced
        to 50 percentage \n")
67  printf("\n                    Initial Starting Current in
        DOL starter, I = %.2f <%.1f A \n",abs(I_c),atand(
        imag(I_c),real(I_c)))
68  printf("\n  For Case(d) When Motor is supplied by
        reduced Voltage of 44V ( Voltage is reduced by 10
        percenatge ) and the reduced frequency is 5Hz \n
        ")
69  printf("\n                    Initial Starting Current in
        DOL starter, I = %.1f <%.1f A \n",abs(I_n),atand(
        imag(I_n),real(I_n)))
70  printf("\n By reducing volatge as well as the
        frequency, the peak starting current at the
        instant os starting is reduced by a fector of %.4
        f of the starting current with the reted volatge
        and frequency \n",Ratio)
71  printf("\n\n      [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
72  printf("\n        WRONGLY PRINTED ANSWERS ARE :- For
        Case(d) When Motor is supplied by reduced Voltage
        of 44V ( Voltage is reduced by 10 percenatge )
        and the reduced frequency is 5Hz,  I = 24.1 <
        25.6 A instead of %.1f < (%.2f) A \n ",abs(I_n),
        atand(imag(I_n),real(I_n)));
73  printf("\n  Ratio of the Starting Current with the
```

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```
       rated  Voltage  and  frequency  to  the  reduced
       Voltage  and  frequency,  Ratio  =  0.2518  instead  of
       %.4f  \n  ",Ratio);
```

Scilab code Exa 5.25 To find range of speed

```
1
2  // ELECTRICAL  MACHINES
3  // R.K.Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  5  :  INDUCTION  MACHINES
8
9  // EXAMPLE  :  5.25
10
11 clear  ;  clc  ;  close  ;  //  Clear  the  work  space  and
      console
12
13
14 // GIVEN  DATA
15
16 m1  =  3;                          //  Total  Number  of
      phase  in  1st  Induction  Motor
17 p1  =  6;                          //  Total  number  of
      Poles  of  1st  Induction  Motor
18 f  =  50;                          //  Frequency  in
      Hertz
19 m2  =  3;                          //  Total  Number  of
      phase  in  2nd  Induction  Motor
20 p2  =  10;                         //  Total  number  of
      Poles  of  2nd  Induction  Motor
21
22
23 // CALCULATIONS
```

```
24
25  Ns1 = (120*f)/p1;                         //
        Synchronous speed of 1st Induction Motor in RPM
26  Ns2 = (120*f)/p2;                         //
        Synchronous speed of 2nd Induction Motor in RPM
27  Nscu = (120*f)/(p1+p2);                   // Speed
        during cumalative casade in RPM
28  Ndiff = (120*f)/(p2-p1);                  // Speed
        during cumalative casade in RPM
29
30
31  // DISPLAY RESULTS
32
33  disp("EXAMPLE : 5.25 : SOLUTION :-");
34  printf("\n (a)  Range of speed is %.f - %.f - %.f -
        %.f RPM \n",Nscu,Ns2,Ns1,Ndiff)
```

Scilab code Exa 5.26 To find current and torque in each cases

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.26
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
```

```scilab
16  m = 3;                              // Total Number of
         phase in Induction Motor
17  p = 4;                              // Total number of
         Poles of Induction Motor
18  f = 50;                             // Frequency in
         Hertz
19  V = 440;                            // Operating Voltage
          of the Inductuon Motor
20  R1 = 0.25;                          // Circuit Parameter
          in Ohms
21  R2 = 0.5;                           // Circuit Parameter
          in Ohms
22  X1 = 1.5;                           // Circuit Parameter
          in Ohms
23  X2 = 1.5;                           // Circuit Parameter
          in Ohms
24
25
26  // CALCULATIONS
27
28  Vph = V/sqrt(3);
         // Per phase Voltage in Volts
29  Ns = (120*f)/p;
         // Synchoronous Speed in RPM
30  Ws = (2*%pi*Ns)/60;
         // Roatation Speed in Radians per Seconds
31
32  // For Case (a) Machine running at, N = 1400 RPM
33
34  N_a = 1400;
         // Machine running in RPM
35  s_a = (Ns-N_a)/Ns;
         // Slip
36  I_2_a = Vph/(R1+(R2/s_a)+(%i*(X1+X2)));
         // Rotor per phase Current referred to the stator
          side in Amphere
37  Pg_a = 3*(abs(I_2_a)^2*R2)/s_a;
         // 3-phase air gap power or Rotor intake Power in
```

```
          Watts
38  T_a = Pg_a/Ws;
        // Torque in Newton-Meter
39
40  // For Case (b) Machine running at, N = 1600 RPM
41
42  N_b = 1600;
        // Machine running in RPM
43  s_b = (Ns-N_b)/Ns;
        // Slip
44  I_2_b = Vph/(R1+(R2/s_b)+(%i*(X1+X2)));
        // Rotor per phase Current referred to the stator
         side in Amphere
45  Pg_b = 3*(abs(I_2_b)^2*R2)/s_b;
        // 3-phase air gap power or Rotor intake Power in
         Watts
46  T_b = Pg_b/Ws;
        // Torque in Newton-Meter
47
48  // For Case (b) Machine running at, N = -100 RPM
49
50  N_c = -100;
        // Machine running in RPM
51  s_c = (Ns-N_c)/Ns;
        // Slip
52  I_2_c = Vph/(R1+(R2/s_c)+(%i*(X1+X2)));
        // Rotor per phase Current referred to the stator
         side in Amphere
53  Pg_c = 3*(abs(I_2_c)^2*R2)/s_c;
        // 3-phase air gap power or Rotor intake Power in
         Watts
54  T_c = -Pg_c/Ws;
                                        // Torque in
      Newton-Meter (minus sign because its counter
      opposing torque)
55
56  // DISPLAY RESULTS
57
```

```
58  disp("EXAMPLE : 5.26 : SOLUTION :−");
59  printf("\n For Case (a) Machine running at, N = 1400
        RPM \n ")
60  printf("\n (a.1) Rotor per phase Current referred to
        the stator side, I2 = %.2f < %.2f A \n",abs(
        I_2_a),atand(imag(I_2_a),real(I_2_a)))
61  printf("\n (a.2) Developed Torque, T = %.2f Nm \n",
        T_a)
62  printf("\n For Case (b) Machine running at, N = 1600
        RPM \n ")
63  printf("\n (a.1) Rotor per phase Current referred to
        the stator side, I2 = %.2f < %.2f A \n",abs(
        I_2_b),atand(imag(I_2_b),real(I_2_b)))
64  disp("    ( angle −157.52 + 180 = 22.48 ) ")
65   printf("\n (a.2) Developed Torque, T = %.2f Nm \n",
        T_b)
66  printf("\n For Case (c) Machine running at, N = −100
        RPM \n ")
67  printf("\n (c.1) Rotor per phase Current referred to
        the stator side, I2 = %.2f < %.2f A \n",abs(
        I_2_c),atand(imag(I_2_c),real(I_2_c)))
68  printf("\n (c.2) Developed Torque, T = %.2f Nm \n",
        T_c)
```

Scilab code Exa 5.27 To find slip at maximum torque and find torque at 5 percent and minus 5 percent of slip

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
```

```scilab
9  // EXAMPLE : 5.27
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 m = 3;                              // Total Number of
       phase in Induction Motor
17 p = 2;                              // Total number of
       Poles of Induction Motor
18 f = 50;                             // Frequency in
       Hertz
19 V = 440;                            // Operating Voltage
        of the Inductuon Motor
20 R1 = 0.25;                          // Circuit Parameter
        in Ohms
21 R2 = 0.25;                          // Circuit Parameter
        in Ohms
22 X1 = 0.75;                          // Circuit Parameter
        in Ohms
23 X2 = 0.75;                          // Circuit Parameter
        in Ohms
24 out_hp = 50;                        // Output of the
      induction motor in HP
25
26
27 // CALCULATIONS
28
29 V1 = V/sqrt(3);
                                                        //
       Phase Voltage in Volts
30 I = (out_hp*746)/(V*sqrt(3));
                                         // Rated Current
       in Amphere
31 sm = R2/(sqrt(R1^2+(X1+X2)^2));
                                        // Slip at Maximum
```

```
        torque both its in Positive and negative sign
32  Ws = 2*%pi*((120*f/p)*(1/60));
                                        // Angular
        Roatation in Radians per Seconds
33  Tm = (3*V1^2)/((2*Ws)*(R1+sqrt((R1^2)+(X1+X2)^2)));
                    // Maximum torque during motoring in
        Newton-Meter
34  Tg = -(3*V1^2)/((2*Ws)*(-R1+sqrt((R1^2)+(X1+X2)^2)))
        ;           // Maximum torque during generating in
        Newton-Meter
35
36  // For Case (a) slip = 0.05
37
38  s_a = 0.05;

        // Slip
39  T_a = (2*Tm)/((s_a/sm)+(sm/s_a));
                                        // Torque in Newton-
        Meter
40
41  // For Case (b) slip = -0.05
42
43  s_b = -0.05;

        // Slip
44  T_b = (2*Tg)/((s_b/sm)+(sm/s_b));
                                        // Torque in Newton-
        Meter
45
46
47  // DISPLAY RESULTS
48
49  disp("EXAMPLE : 5.27 : SOLUTION :-");
50  printf("\n Maximim Torque during Motoring, Tm = %.f
        N-m \n",Tm)
51  printf("\n Maximim Torque during Generating, Tm = %
        .2f N-m \n",Tg)
52  printf("\n For Case (a) slip = 0.05 \n ")
```

```
53  printf("\n (a.1) Torque, T = %.2f Nm \n",T_a)
54  printf("\n For Case (b) slip = −0.05 \n ")
55  printf("\n (b.1) Torque, T = %.2f Nm \n",T_b)
```

Scilab code Exa 5.28 To find starting torque and running torque

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.28
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  m = 3;                          // Total Number of
        phase in Induction Motor
17  p = 2;                          // Total number of
        Poles of Induction Motor
18  f = 50;                         // Frequency in
        Hertz
19  V = 440;                        // Operating Voltage
        of the Inductuon Motor in Volts
20  R0 = 0.5;                       // Circuit Parameter
        in Ohms
21  Ri = 0.05;                      // Circuit Parameter
        in Ohms
22  X0 = 0.2;                       // Circuit Parameter
```

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```
        in Ohms
23  Xi = 0.9;                          // Circuit Parameter
        in Ohms
24  s = 0.07;                          // Slip
25
26
27  // CALCULATIONS
28
29  Ws = 2*%pi*f;
                                                        //
        Synchronous  speed  in  Radins  per  second
30  v = V/sqrt(3);
                                                        //
        Phase  Voltage  in  Volts
31  Io = v/(R0+%i*X0);
                                                   //
        Starting  Current  in  the  outer  cage  in  Amphere
32  Ii = v/(Ri+%i*Xi);
                                                   //
        Starting  Current  in  the  inner  cage  in  Amphere
33  Tst = ((3*abs(Io)^2*R0)/Ws)+((3*abs(Ii)^2*Ri)/Ws);
                  // Starting  torque  i.e  at  standstill ,  s
        =1
34  Ios = v/((R0/s)+(%i*X0));
                                              // Current  in
        the  outer  cage  at  slip  = 0.07
35  Iis = v/((Ri/s)+(%i*Xi));
                                              // Current  in
        the  outer  cage  at  slip  = 0.07
36  T = ((3*abs(Ios)^2*R0)/(s*Ws))+((3*abs(Iis)^2*Ri)/(s
        *Ws));            // Starting  torque  at  s=0.07  in
        Newton−Meter
37
38
39  // DISPLAY RESULTS
40
41  disp("EXAMPLE : 5.28 : SOLUTION :−");
42  printf("\n (a) Starting  torque ,  Tst = %.2f Nm \n",
```

```
     Tst)
43  printf(" \n (b) Running torque at slip = 0.07, T = %
      .2 f Nm \n",T)
```

Scilab code Exa 5.29 To find running torque

```
1
2   // ELECTRICAL MACHINES
3   // R.K. Srivastava
4   // First Impression 2011
5   // CENGAGE LEARNING INDIA PVT. LTD
6
7   // CHAPTER : 5 : INDUCTION MACHINES
8
9   // EXAMPLE : 5.29
10
11  clear ; clc ; close ; // Clear the work space and
      console
12
13
14  // GIVEN DATA
15
16  p = 4;                        // Total number of
      Poles of Induction Motor
17  f = 50;                       // Frequency in
      Hertz
18  V = 440;                      // Operating Voltage
      of the Inductuon Motor in Volts
19  out = 25*1000;                // Power rating of
      the Induction motor in Watts
20  R0 = 2.5;                     // Circuit Parameter
      in Ohms
21  Ri = 0.5;                     // Circuit Parameter
      in Ohms
22  X0 = 1.0;                     // Circuit Parameter
```

```scilab
         in Ohms
23  Xi = 5.0;                               // Circuit Parameter
         in Ohms
24  Rc = 500;                               // Circuit Parameter
         in Ohms
25  R1 = 0.2;                               // Circuit Parameter
         in Ohms
26  Xm = 50;                                // Circuit Parameter
         in Ohms
27  X123 = 2.0;                             // Circuit Parameter
         in Ohms
28  s = 0.05;                               // Slip
29
30
31  // CALCULATIONS
32
33  Ws = (2*%pi*120*f)/(p*60);
                                            // Synchronous
      speed in Radins per second
34  Zo = (R0/s)+(%i*X0);
                                                    // Outer
      cage impedance at slip = 0.05 in Ohms
35  Zi = (Ri/s)+(%i*Xi);
                                                    // Inner
      cage impedance at slip = 0.05 in Ohms
36  Z = (R1+%i*X123)+((Zo*Zi)/(Zo+Zi));
                              // Total impdance in Ohms
37  I = V/Z;

      // Current in the Cage winding in Amphere
38  Io = (I*((Zo*Zi)/(Zo+Zi)))/Zo;
                              // Current in the
      outer cage in Amphere
39  Ii = (I*((Zo*Zi)/(Zo+Zi)))/Zi;
                              // Current in the
      inner cage in Amphere
40  T = ((3*abs(Io)^2*R0)/(s*Ws))+((3*abs(Ii)^2*Ri)/(s*
      Ws));   // Starting torque in Newton-Meter
```

```
41
42
43  // DISPLAY RESULTS
44
45  disp("EXAMPLE : 5.29 : SOLUTION :−");
46  printf("\n (a) Torque at slip %.2f, T = %.2f Nm \n",
        s,T)
```

Scilab code Exa 5.30 To find input current pf and running torque

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 5 : INDUCTION MACHINES
8
9  // EXAMPLE : 5.30
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 m = 1;                          // Total Number of
       phase in Induction Motor
17 p = 2;                          // Total number of
       Poles of Induction Motor
18 f = 50;                         // Frequency in
       Hertz
19 V = 220;                        // Operating Voltage
        of the Inductuon Motor in Volts
20 R1 = 10;                        // Circuit Parameter
```

```
                   in Ohms
21  R2 = 11;                                // Circuit Parameter
                   in Ohms
22  X1 = 12;                                // Circuit Parameter
                   in Ohms
23  X2 = 12;                                // Circuit Parameter
                   in Ohms
24  Xm = 125;                               // Circuit Parameter
                   in Ohms
25  s = 0.03;                               // Slip
26
27
28  // CALCULATIONS
29
30  Zf = ((%i*Xm/2)*((R2/(2*s))+(%i*X2/2)))/((%i*Xm/2)+(
        R2/(2*s))+(%i*X2/2));                        // Impedance
        offered by the forward field in Ohms
31  Zb = ((%i*Xm/2)*((R2/(2*(2-s)))+(%i*X2/2)))/((%i*Xm
        /2)+(R2/(2*(2-s)))+(%i*X2/2));           // Impedance
         offered by the backward field in Ohms
32  Z = (R1+%i*X1)+Zf+Zb;
        // Total Impedance in Ohms
33  I = V/Z;
        // Total input current in Amphere
34  pf = cosd(atand(imag(I),real(I)));
        // Power Factor (lagging)
35  Vf = I*Zf;
        // Forward Volatge at slip 0.03 in Volts
36  Vb = I*Zb;
        // Backward Volatge at slip 0.03 in Volts
37  If = Vf/(0.5*R2/s);
        // Forward Current in Amphere
38  Ib = Vb/(0.5*R2/(2-s));
        // Forward Current in Amphere
39  Ws = 2*%pi*f;
        // Synchronous Speed in radians per second
40  T = ((0.5*If^2*R2)/(s*Ws))-((0.5*Ib^2*R2)/((2-s)*Ws
        ));            // Starting torque
```

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```
41
42
43 // DISPLAY RESULTS
44
45 disp("EXAMPLE : 5.30 : SOLUTION :−");
46 printf("\n (a) Input Current, I = %.2f < %.f A \n",
      abs(I),atand(imag(I),real(I)))
47 printf("\n (b) Power factor, pf = %.2f Lagging \n",
      pf)
48 printf("\n (c) Developed Torque, T = %.3f Nm \n",T)
```

Scilab code Exa 5.31 To find equivalent circuit parameters of the induction motor current and pf

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 5 : INDUCTION MACHINES
8
9 // EXAMPLE : 5.31
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 Wsc = 900;                        // Power at Blocked
      Rotor test in Watts
17 Vsc = 200;                        // Voltage at Blocked
      Rotor test in Volts
18 Isc = 5.0;                        // Current at Blocked
```

```scilab
        Rotor  test  in  Amphere
19  Wo = 60;                              // Power  at  No-load
      test  in  Watts
20  Vo = 220;                             // Voltage  at  No-load
        test  in  Volts
21  Io = 1.5;                             // Current  at  No-load
        test  in  Amphere
22  m = 1;                                // Total  Number  of
      phase  in  Induction  Motor
23  p = 4;                                // Total  number  of
      Poles  of  Induction  Motor
24  V = 220;                              // Operating  voltage
      of  the  Induction  motor  in  Volts
25  f = 50;                               // Frequency  in  Hertz
26  s = 0.07;                             // Slip
27  R1 = 12;                              // Resistance  of  the
      main  primary  winding  in  Ohms
28
29
30  // CALCULATIONS
31
32  Zsc = Vsc/Isc;                        // Impedance  in
      Blocked  Rotor  test  in  Ohms
33  Rsc = Wsc/(Isc^2);                    // Resistance  in
      Blocked  Rotor  test  in  Ohms
34  Xsc = sqrt((Zsc^2)-(Rsc^2));          // Reactance  in
      Blocked  Rotor  test  in  Ohms
35  Xl1 = Xsc/2;                          // Leakage
      reactance  of  stator  and  rotor  to  be  equal  in  Ohms
36  Xl2 = Xsc/2;                          // Leakage
      reactance  of  stator  and  rotor  to  be  equal  in  Ohms
37  R2 = Rsc-R1;                          // Equivalent
      resistance  of  rotor  referred  to  stator  in  Ohms
38  Z0 = Vo/Io;                           // Impedance  in
      Blocked  Rotor  test  in  Ohms
39  R0 = Wo/(Io^2);                       // Resistance  in
      Blocked  Rotor  test  in  Ohms
40  X0 = sqrt((Z0^2)-(R0^2));             // Reactance  in
```

```
        Blocked  Rotor  test  in  Ohms
41  Wloss = Wo - ((Io^2)*(R1+R2));           // Loss  in  Watts
42  Xm_half = X0-Xl1-Xl2/2;
43  R2f = (R2/s)+((%i*Xl2)/2);
                                    // Forward  resiatance
        in  Ohms
44  Zf = ((%i*Xm_half)*R2f)/(%i*Xm_half+R2f);
                      // Total  Forward  impedance  in  Ohms
45  R2b = (R2/(2-s))+((%i*Xl2)/2);
                                  // Backward  resiatance  in
        Ohms
46  Zb = ((%i*Xm_half)*R2b)/(%i*Xm_half+R2b);
                      // Total  Backward  impedance  in  Ohms
47  Z = Zf+Zb+(R1+%i*Xl1);
                                          // Total
        impedance  in  Ohms
48  I = V/Z;
                                                    //
        Motor  Current  in  Amphere
49  pf = cosd(atand(imag(I),real(I)));
                                  // Power  Factor  (lagging)
50
51
52  // DISPLAY RESULTS
53
54  disp("EXAMPLE : 5.31 : SOLUTION :-");
55  printf("\n Circuit  Parameters  are  \n\n (a) Leakage
        reactance  of  stator  and  rotor  to  be  equal ,  Xl1 =
        Xl2 = %.2 f  Ohms  \n", Xl1)
56  printf("\n (b) Equivalent  resistance  of  rotor
        referred  to  stator ,  R2 = %. f  Ohms  \n", R2)
57  printf("\n (c) Total  Forward  impedance ,  Zf = %.1 f <
        %.2 f  Ohms  \n", abs(Zf), atand(imag(Zf), real(Zf)))
58  printf("\n (c) Total  Backward  impedance ,  Zb = %.2 f <
        %.2 f  Ohms  \n", abs(Zb), atand(imag(Zb), real(Zb)))
59  printf("\n (d) Total  impedance ,  Z = %.2 f < %.2 f  Ohms
        \n", abs(Z), atand(imag(Z), real(Z)))
60  printf("\n (e) Input  Current ,  I = %.2 f < %.2 f  A  \n",
```

```
       abs ( I ) , atand ( imag ( I ) , real ( I ) ) )
61 printf ( " \n  ( f )  Power  factor ,  pf  =  %.2 f  Lagging  \n" ,
       pf )
```

Scilab code Exa 5.32 To find To find equivalent circuit parameters of the induction motor current pf forwrad torque backward torque net torque

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  5  :  INDUCTION  MACHINES
8
9  // EXAMPLE  :  5.32
10
11 clear  ;  clc  ;  close  ;  // Clear  the  work  space  and
       console
12
13
14 // GIVEN  DATA
15
16 Wsc  =  600;                       // Power  at  Blocked
       Rotor  test  in  Watts
17 Vsc  =  125;                       // Voltage  at  Blocked
        Rotor  test  in  Volts
18 Isc  =  15.0;                      // Current  at  Blocked
        Rotor  test  in  Amphere
19 Wo  =  360;                        // Power  at  No−load
       test  in  Watts
20 Vo  =  220;                        // Voltage  at  No−load
        test  in  Volts
21 Io  =  6.5;                        // Current  at  No−load
        test  in  Amphere
```

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```scilab
22  m = 1;                              // Total Number of
        phase in Induction Motor
23  p = 4;                              // Total number of
        Poles of Induction Motor
24  V = 220;                            // Operating voltage
        of the Induction motor in Volts
25  f = 50;                             // Frequency in Hertz
26  s = 0.05;                           // Slip
27  R1 = 1.2;                           // Resistance of the
        main primary winding in Ohms
28
29
30  // CALCULATIONS
31
32  Zlr = Vsc/Isc;                      // Impedance in
        Blocked Rotor test in Ohms
33  Rlr = Wsc/(Isc^2);                  // Resistance in
        Blocked Rotor test in Ohms
34  Xlr = sqrt((Zlr^2)-(Rlr^2));        // Reactance in
        Blocked Rotor test in Ohms
35  Xl1 = Xlr/2;                        // Leakage
        reactance of stator and rotor to be equal in Ohms
36  Xl2 = Xlr/2;                        // Leakage
        reactance of stator and rotor to be equal in Ohms
37  R2 = (Rlr-R1);                      // Equivalent
        resistance of rotor referred to stator in Ohms
38  R2_half = R2/2;                     // Equivalent
        resistance of rotor referred to stator in Ohms
39  Z0 = Vo/Io;                         // Impedance in
        Blocked Rotor test in Ohms
40  R0 = Wo/(Io^2);                     // Resistance in
        Blocked Rotor test in Ohms
41  X0 = sqrt((Z0^2)-(R0^2));           // Reactance in
        Blocked Rotor test in Ohms
42  Wloss = Wo - ((Io^2)*(R1+R2));      // Loss in Watts
43  Xm_half = X0-Xl1-Xl2/2;
44  R2f = (R2/(2*s))+((%i*Xl2)/2);
                                        // Forward resiatance in
```

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```
     Ohms
45 Zf = ((%i*Xm_half)*R2f)/(%i*Xm_half+R2f);
                    // Total Forward impedance in Ohms
46 R2b = (R2/(2*(2-s)))+((%i*Xl2)/2);
                             // Backward resiatance in
     Ohms
47 Zb = ((%i*Xm_half)*R2b)/(%i*Xm_half+R2b);
                    // Total Backward impedance in Ohms
48 Z = Zf+Zb+(R1+%i*Xl1);
                                              // Total
     impedance in Ohms
49 I = V/Z;
                                                      //
     Motor Current in Amphere
50 pf = cosd(atand(imag(I),real(I)));
                             // Power Factor (lagging)
51 Vf = I*Zf;
                                                      //
     Voltage across forward impedance in Volts
52 If = Vf/R2f;
                                                      //
     Forward current producing torque in Amphere
53 Tf = ((abs(If)^2)*R2)/(2*s);
                                    // Forward torque in
     synchronous Watts
54 Vb = I*Zb;
                                                      //
     Voltage across Backward impedance in Volts
55 Ib = Vb/R2b;
                                                      //
     Backward current producing torque in Amphere
56 Tb = ((abs(Ib)^2)*R2)/(2*(2-s));
                                  // Backward torque in
     synchronous Watts
57 T = Tf-Tb;
                                                      //
     Net torque in Synchronous Watts
58
```

```
59
60  // DISPLAY RESULTS
61
62  disp("EXAMPLE : 5.32 : SOLUTION :-");
63  printf("\n Circuit Parameters are \n\n (a) Leakage
        reactance of stator and rotor to be equal, Xl1 =
        Xl2 = %.2f Ohms \n",Xl1)
64  printf("\n (b) Equivalent resistance of rotor
        referred to stator, R2 = %.2f Ohms \n",R2)
65  printf("\n (c) Total Forward impedance, Zf = %.1f <
        %.2f Ohms \n",abs(Zf),atand(imag(Zf),real(Zf)))
66  printf("\n (c) Total Backward impedance, Zb = %.2f <
        %.2f Ohms \n",abs(Zb),atand(imag(Zb),real(Zb)))
67  printf("\n (d) Total impedance, Z = %.2f < %.2f Ohms
        \n",abs(Z),atand(imag(Z),real(Z)))
68  printf("\n (e) Input Current, I = %.2f < %.f A \n",
        abs(I),atand(imag(I),real(I)))
69  printf("\n (f) Power factor, pf = %.4f Lagging \n",
        pf)
70  printf("\n (g) Forward torque, Tf = %.2f Synchronous
        Watts \n",Tf)
71  printf("\n (h) Backward torque, Tb = %.2f
        Synchronous Watts \n",Tb)
72  printf("\n (i) Net torque, T = %.2f Synchronous
        Watts \n",T)
```

Chapter 6

Synchronous Machines

Scilab code Exa 6.1 To find number of poles in each cases

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.1
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 f = 50;                               // Generating
       Frequency in Hertz
17
18
19 // CALCULATIONS
```

```
20  // For Case(a)
21
22  Ns_a = 3000;                              // Synchronous
        speed in RPM
23  p_a = (120*f)/Ns_a;                       // Number of
        poles
24
25  // For Case(b)
26
27  Ns_b = 1000;                              // Synchronous
        speed in RPM
28  p_b = (120*f)/Ns_b;                       // Number of
        poles
29
30  // For Case(c)
31
32  Ns_c = 300;                               // Synchronous
        speed in RPM
33  p_c = (120*f)/Ns_c;                       // Number of
        poles
34
35  // For Case(d)
36
37  Ns_d = 40;                                // Synchronous
        speed in RPM
38  p_d = (120*f)/Ns_d;                       // Number of
        poles
39
40
41  // DISPLAY RESULTS
42
43  disp("EXAMPLE : 6.1 : SOLUTION :-") ;
44  printf("\n For Case(a) Ns = %.f, p = %.f \n ",Ns_a,
        p_a);
45  printf("\n For Case(b) Ns = %.f, p = %.f \n ",Ns_b,
        p_b);
46  printf("\n For Case(c) Ns = %.f, p = %.f \n ",Ns_c,
        p_c);
```

```
47  printf(" \n  For  Case(d)  Ns = %.f ,  p = %.f  \n  ",Ns_d,
        p_d);
```

Scilab code Exa 6.2 To find frequency

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.2
10
11 clear ; clc ; close ;  // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 f = 60;                             // Generating
       Frequency in Hertz
17 Ns = 1200;                          // Synchronous
       speed in RPM
18 Ns_r = 1000;                        // Alternator
       running speed in RPM
19
20
21 // CALCULATIONS
22
23 p = (120*f)/Ns;                     // Total number
       of poles
24 f_r = (p*Ns_r)/120;                 // Alternator
       running frequency in Hertz
```

```
25
26
27  // DISPLAY RESULTS
28
29  disp("EXAMPLE : 6.2 : SOLUTION :-") ;
30  printf("\n Alternator running frequency , f = %. f Hz
        \n ",f_r);
```

Scilab code Exa 6.3 To find Synchronous speed in each cases

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.3
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  p = 2;                                          // Total
        number of poles
17
18
19  // CALCULATIONS
20  // For Case(a)
21
22  f_a = 10;                                       //
        Frequency in Hertz
```

```
23  Ns_a = (120*f_a)/p;                           //
        Synchronous  speed  in  RPM
24
25  // For Case(b)
26
27  f_b = 50;                                      //
        Frequency  in  Hertz
28  Ns_b = (120*f_b)/p;                            //
        Synchronous  speed  in  RPM
29
30  // For Case(c)
31
32  f_c = 60;                                      //
        Frequency  in  Hertz
33  Ns_c = (120*f_c)/p;                            //
        Synchronous  speed  in  RPM
34
35  // For Case(d)
36
37  f_d = 100;                                     //
        Frequency  in  Hertz
38  Ns_d = (120*f_d)/p;                            //
        Synchronous  speed  in  RPM
39
40  // For Case(e)
41
42  f_e = 400;                                     //
        Frequency  in  Hertz
43  Ns_e = (120*f_e)/p;                            //
        Synchronous  speed  in  RPM
44
45
46  // DISPLAY RESULTS
47
48  disp("EXAMPLE : 6.3 : SOLUTION :-");
49  printf("\n For Case (a) When f = %.f, Synchronous
        speed, Ns = %.f RPM \n",f_a,Ns_a)
50  printf("\n For Case (b) When f = %.f, Synchronous
```

```
         speed , Ns = %. f RPM \n",f_b,Ns_b)
51 printf (" \n For Case (c) When f = %.f , Synchronous
         speed , Ns = %. f RPM \n",f_c,Ns_c)
52 printf (" \n For Case (d) When f = %.f , Synchronous
         speed , Ns = %. f RPM \n",f_d,Ns_d)
53 printf (" \n For Case (e) When f = %.f , Synchronous
         speed , Ns = %. f RPM \n",f_e,Ns_e)
```

Scilab code Exa 6.4 To find leakage reactance and open circuit EMF in each cases

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9 // EXAMPLE : 6.4
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 printf (" \n EXAMPLE :  6.4  :  \n\n           Given  Data
       \n");
17 printf (" \n Voc(v)  215       284       320       380
          400       422       452       472       488
          508       520       532       540       552
          560 \n");
18 printf (" \n If(A)     6.5       8         9        10
            11        12        14        15        16
```

```scilab
                 17        18          19          20          22
              24 \n\n");
19  m = 3;                              // Total Number of
       phase
20  p = 6;                              // Total number of
       Poles
21  V = 400;                            // Operating voltage
       in Volts
22  I = 13.5;                           // Operating current
       in Amphere
23  N = 1000;                           // Speed in RPM
24  Ia_scc = 13.5;                      // SCC test Armature
       current in Amphere at If = 9.5 A
25  If_scc = 9.5;                       // SCC test field
       Rated current in Amphere
26  Ia_zpf = 13.5;                      // ZPF test Armature
       current in Amphere at If = 24 A
27  If_zpf = 24;                        // ZPF test field
       Rated current in Amphere
28
29
30  // CALCULATIONS
31  // Some of the data obtained from OCC and SCC test
       Graph or Pottier triangle in Figure6.15 & Page no
       :-386
32  Ra = 1.0;                                           //
       Armature resistance in Ohms
33
34  // For case (a)
35
36  BC = 120;                                           // Open
       circuit Voltage in Volts obtained from OCC and
       SCC test Graph or Pottier triangle Figure6.15 &
       Page no:-386
37  Xl = BC/(sqrt(3)*Ia_scc);                           // Per
       phase leakage reactance in Ohms
38
39
```

```
40  // For Case (b.1) 0.8 pf Lagging
41
42  pfa_b1 = acosd(0.8);

      // Power factor angle in degree
43  Er_b1 = (V/sqrt(3))+(Ia_scc*(cosd(pfa_b1)-%i*sind(
      pfa_b1))*(Ra+%i*Xl));        // Induced Voltage in
      Volts
44  R_b1 = 10; A_b1 = 9.5;

      //From OCC the field current required for Er_b1 (
      Should be in Line−line Voltage) Er_b1 = 379.12V
      will get R_b1 & A_b1 value Respectively from SCC
      (Figure6.15 & Page no:−386)
45  angle_b1 = 136.35;

      // Angle between R_b1 & A_b1 (figure 6.16(a) &
      Page no:−388) = 90'+9.48'+36.87' = 136.35'
46  F_b1 = sqrt((R_b1^2)+(A_b1^2)-(2*R_b1*A_b1*cosd(
      angle_b1)));                  // From phasor diagram
      in figure 6.16(a) & Page no:−388 the neccessary
      field excitation in Amphere
47  Eo_b1 = 525;

      // Corresponding to field current F_b1 = 18.12 A
      the open circuit EMF from OCC is 525 V (Figure6
      .15 & Page no:−386)
48  r_b1 = 100*((Eo_b1-V)/V);

      // Percentage regulation
49
50
51  // For Case (b.2) 0.8 pf Leading
52
53  pfa_b2 = acosd(0.8);

      // Power factor angle in degree
54  Er_b2 = (V/sqrt(3))+(Ia_scc*(cosd(pfa_b2)+%i*sind(
```

```
      pfa_b2))*(Ra+%i*Xl));        // Induced Voltage in
      Volts
55 R_b2 = 8.3; A_b2 = 9.5;

      //From OCC the field current required for Er_b2 (
      Should be in Line-line Voltage) Er_b1 = 363.71 V
      will get R_b2 & A_b2 value Respectively from SCC
      (Figure6.15 & Page no:-386)
56 angle_b2 = 70.61;

      // Angle between R_b2 & A_b2 (figure 6.16(b) &
      Page no:-388) = 90'+17.48'-36.87' = 70.61'
57 F_b2 = sqrt((R_b2^2)+(A_b2^2)-(2*R_b2*A_b2*cosd(
      angle_b2)));                 // From phasor diagram
      in figure 6.16(b) & Page no:-388 the neccessary
      field excitation in Amphere
58 Eo_b2 = 338;

      // Corresponding to field current F_b2 = 10.36 A
      the open circuit EMF from OCC is 338 V (Figure6
      .15 & Page no:-386)
59 r_b2 = 100*((Eo_b2-V)/V);

      // Percentage regulation
60
61
62 // For Case (b.3) Unity pf Leading
63
64 pfa_b3 = acosd(1.0);

      // Power factor angle in degree
65 Er_b3 = (V/sqrt(3))+(Ia_scc*(cosd(pfa_b3)-%i*sind(
      pfa_b3))*(Ra+%i*Xl));        // Induced Voltage in
      Volts
66 R_b3 = 13; A_b3 = 9.5;

      //From OCC the field current required for Er_b3 (
      Should be in Line-line Voltage) Er_b1 = 440.30 V
```

```
         will get R_b3 & A_b3 value Respectively from SCC
         (Figure6.15 & Page no:-386)
67  angle_b3 = 105.81;

         // Angle between R_b3 & A_b3 (figure 6.16(c) &
         Page no:-388) = 90'+15.81' = 105.81'
68  F_b3 = sqrt((R_b3^2)+(A_b3^2)-(2*R_b3*A_b3*cosd(
         angle_b3)));                     // From phasor diagram
         in figure 6.16(c) & Page no:-388 the neccessary
         field excitation in Amphere
69  Eo_b3 = 520;

         // Corresponding to field current F_b2 = 18.10 A
         the open circuit EMF from OCC is 520 V (Figure6
         .15 & Page no:-386)
70  r_b3 = 100*((Eo_b3-V)/V);

         // Percentage regulation
71
72
73  // For Case (b.4) ZPF Lagging
74
75  pfa_b4 = acosd(0);

         // Power factor angle in degree
76  Er_b4 = (V/sqrt(3))+(Ia_scc*(cosd(pfa_b4)-%i*sind(
         pfa_b4))*(Ra+%i*Xl));          // Induced Voltage in
         Volts
77  R_b4 = 18; A_b4 = 9.5;

         //From OCC the field current required for Er_b4 (
         Should be in Line-line Voltage) Er_b4 = 521 V
         will get R_b4 & A_b4 value Respectively from SCC
         (Figure6.15 & Page no:-386)
78  angle_b4 = 177.57;

         // Angle between R_b4 & A_b4 = 90'-2.43'+90' =
         177.57'
```

```
79  F_b4 = sqrt((R_b4^2)+(A_b4^2)-(2*R_b4*A_b4*cosd(
       angle_b4)));                    // The neccessary field
        excitation in Amphere
80  Eo_b4 = 570;

       // Corresponding to field current F_b4 = 27.50 A
       the open circuit EMF from OCC is 525 V (Figure6
       .15 & Page no:-386)
81  r_b4 = 100*((Eo_b4-V)/V);

       // Percentage regulation
82
83
84  // For Case (b.4) ZPF Lagging
85
86  pfa_b5 = acosd(0);

       // Power factor angle in degree
87  Er_b5 = (V/sqrt(3))+(Ia_scc*(cosd(pfa_b5)+%i*sind(
       pfa_b5))*(Ra+%i*Xl));          // Induced Voltage in
       Volts
88  R_b5 = 6.0; A_b5 = 9.50;

       //From OCC the field current required for Er_b5 (
       Should be in Line-line Voltage) Er_b5 = 280.70 V
       will get R_b5 & A_b5 value Respectively from SCC
       (Figure6.15 & Page no:-386)
89  angle_b5 = 4.77;

       // Angle between R_b5 & A_b5 = 90'-4.77'-90' =
       4.77'
90  F_b5 = sqrt((R_b5^2)+(A_b5^2)-(2*R_b5*A_b5*cosd(
       angle_b5)));                    // The neccessary field
        excitation in Amphere
91  Eo_b5 = 135;

       // Corresponding to field current F_b4 = 27.50 A
       the open circuit EMF from OCC is 135 V (Figure6
```

```
92  r_b5 = 100*((Eo_b5-V)/V);

        // Percentage  regulation
93
94
95  // DISPLAY RESULTS
96
97  disp(" SOLUTION :-");
98  printf("\n (a)  Per phase leakage reactance, Xl = %
        .2f Ohms \n",Xl)
99  printf("\n For Case (b.1) 0.8 pf Lagging \n  Open
        circuit EMF, EMF = %.f V \n",Eo_b1)
100 printf("\n Percenatge Regulation, R = %.2f
        Percenatge \n",r_b1)
101 printf("\n For Case (b.2) 0.8 pf Leading \n  Open
        circuit EMF, EMF = %.f V \n",Eo_b2)
102 printf("\n Percenatge Regulation, R = %.1f
        Percenatge \n",r_b2)
103 printf("\n For Case (b.3) Unity pf Lagging \n  Open
        circuit EMF, EMF = %.f V \n",Eo_b3)
104 printf("\n Percenatge Regulation, R = %.f Percenatge
         \n",r_b3)
105 printf("\n For Case (b.4) ZPF Lagging \n  Open
        circuit EMF, EMF = %.f V\n",Eo_b4)
106 printf("\n Percenatge Regulation, R = %.2f
        Percenatge \n",r_b4)
107 printf("\n For Case (b.5) ZPF Leading \n  Open
        circuit EMF, EMF = %.f V \n",Eo_b5)
108 printf("\n Percenatge Regulation, R = %.2f
        Percenatge \n\n",r_b5)
109 disp(" Calculated Answer in Tabular Column")
110 printf("\n   Power Factor                    0.8 Lag
          0.8 Lead        1.0        ZPF Lag       ZPF
        Lead \n")
111 printf("\n Open circuit EMF (V)            %.f
               %.f                %.f         %.f               %
        .f \n",Eo_b1,Eo_b2,Eo_b3,Eo_b4,Eo_b5)
```

```
112  printf("\n Percenatge  Regulation            %.2 f
            %.1 f             %.f .        %.2 f        %.2 f
       \n",r_b1,r_b2,r_b3,r_b4,r_b5)
```

Scilab code Exa 6.5a To find Synchronous reactance and open circuit EMF in each cases

```
1
2   // ELECTRICAL MACHINES
3   // R.K. Srivastava
4   //  First  Impression  2011
5   // CENGAGE LEARNING INDIA PVT. LTD
6
7   // CHAPTER : 6  : SYNCHRONOUS MACHINES
8
9   // EXAMPLE :  6.5 a
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  printf("\n EXAMPLE :  6.5 a( Data  is  same  as  Example
        6.4):  \n\n          Given  Data  \n");
17  printf("\n Voc(v)   215        284        320        380
            400       422       452       472       488
            508       520       532       540       552
            560  \n");
18  printf("\n  If (A)      6.5        8         9         10
            11        12        14        15        16
            17        18        19        20        22
            24  \n\n");
19  m = 3;                           // Total Number of
        phase  in  Induction  Motor
```

```
20  p = 6;                                  // Total number of
        Poles of Induction Motor
21  V = 400;                                // Operating voltage
        of the Induction motor in Volts
22  I = 13.5;                               // Operating current
        of the Induction motor in Amphere
23  N = 1000;                               // speed of the
        Induction motor in RPM
24  Ia_scc = 13.5;                          // SCC test Armature
        current in Amphere at If = 9.5 A
25  If_scc = 9.5;                           // SCC test field
        Rated current in Amphere
26  Ia_zpf = 13.5;                          // ZPF test Armature
        current in Amphere at If = 24 A
27  If_zpf = 24;                            // ZPF test field
        Rated current in Amphere
28
29
30  // CALCULATIONS
31  // Some of the data obtained from OCC and SCC test
        Graph or Pottier triangle in Figure6.15 & Page no
        :-386
32  Ra = 1.0;                                               //
        Armature resistance in Ohms
33  v = V/sqrt(3);                                  // Rated
        phase Voltage in Volts
34
35  // For case (a)
36
37  EMF_a1 = 345;                                        // From
        OCC and SCC test Graph or Pottier triangle in
        Figure6.15 & Page no:-386 open-circuit line-line
        voltage per phase is 345vVfor If = 9.50A in Volts
38  Zs_a1 = EMF_a1/(Ia_zpf*sqrt(3));              //
        Unsaturated synchronous impedance at If=9.50A in
        Ohms
39  Xs_a1 = sqrt((Zs_a1^2)-(Ra^2));              //
        Synchronous reactance at If =9.50A in Ohms
```

208

```
40  Ia_a2 = 15.75;                                         //
        Current from SCC in Figure6.15 & Page no:-386 is
        15.75A for correspounding to the rated Voltage in
         Volts
41  Zs_a2 = V/(Ia_a2*sqrt(3));                             //
        Unsaturated synchronous impedance at If=9.50A in
        Ohms
42  Xs_a2 = sqrt((Zs_a2^2)-(Ra^2));                        //
        Synchronous reactance at If =9.50A in Ohms
43
44  // For Case (b.1) 0.8 pf Lagging
45
46  pfa_b1 = acosd(0.8);

        // Power factor angle in degree
47  real_b1 = (v+Ia_zpf*Ra*cosd(pfa_b1)+Ia_zpf*Xs_a1*
        sind(pfa_b1));
48  imag_b1 = (Ia_zpf*Xs_a1*cosd(pfa_b1)-Ia_zpf*Ra*sind(
        pfa_b1));
49  E_b1 = sqrt(real_b1^2+imag_b1^2);
                                              // Induced
         Voltage pr phase in Volts from Figure6.19 (a) &
        Page no:-394 shows the phasor diagram for lagging
         pf
50  del_b1 = atand(imag_b1/real_b1);
                                              // Power
        angle in degree
51  r_b1 = 100*(E_b1-v)/v;

        // Percantage regulation
52
53
54  // For Case (b.2) 0.8 pf Leading
55
56  pfa_b2 = acosd(0.8);

        // Power factor angle in degree
57  real_b2 = (v+Ia_zpf*Ra*cosd(pfa_b2)-Ia_zpf*Xs_a1*
```

```
        sind ( pfa_b2 ) );
58  imag_b2 = ( Ia_zpf * Xs_a1 * cosd ( pfa_b2 )+ Ia_zpf * Ra * sind (
        pfa_b2 ) );
59  E_b2 = sqrt ( real_b2 ^2+ imag_b2 ^2);
                                                        // Induced
        Voltage pr phase in Volts from Figure6 .19 ( b ) &
        Page no : -394 shows the phasor diagram for leading
         pf
60  del_b2 = atand ( imag_b2 / real_b2 );
                                                        // Power
        angle in degree
61  r_b2 = 100*( E_b2 - v )/ v ;

        // Percantage regulation
62
63
64  // For Case ( b .3) Unity pf
65
66  pfa_b3 = acosd (1.0);

        // Power factor angle in degree
67  real_b3 = ( v + Ia_zpf * Ra );
68  imag_b3 = ( Ia_zpf * Xs_a1 );
69  E_b3 = sqrt ( real_b3 ^2+ imag_b3 ^2);
                                                        // Induced
        Voltage pr phase in Volts from Figure6 .19 ( a ) &
        Page no : -394 shows the phasor diagram for unity
        pf
70  del_b3 = atand ( imag_b3 / real_b3 );
                                                        // Power
        angle in degree
71  r_b3 = 100*( E_b3 - v )/ v ;

        // Percantage regulation
72
73  // For Case ( b .4) ZPF pf Lagging
74
75  pfa_b4 = acosd (0);
```

```
        // Power factor angle in degree
76 real_b4 = (v+Ia_zpf*Xs_a1);
77 imag_b4 = (-Ia_zpf*Ra);
78 E_b4 = sqrt(real_b4^2+imag_b4^2);
                                                // Induced
        Voltage pr phase in Volts ZPF for lagging pf
79 del_b4 = atand(imag_b4/real_b4);
                                                        // Power
        angle in degree
80 r_b4 = 100*(E_b4-v)/v;

        // Percantage regulation
81
82 // For Case (b.5) ZPF pf Leading
83
84 pfa_b5 = acosd(0);

        // Power factor angle in degree
85 real_b5 = (v-Ia_zpf*Xs_a1);
86 imag_b5 = (Ia_zpf*Ra);
87 E_b5 = sqrt(real_b5^2+imag_b5^2);
                                                // Induced
        Voltage pr phase in Volts ZPF for lagging pf
88 del_b5 = atand(imag_b5/real_b5);
                                                        // Power
        angle in degree
89 r_b5 = 100*(E_b5-v)/v;

        // Percantage regulation
90
91
92
93
94 // DISPLAY RESULTS
95
96 disp(" SOLUTION :-");
97 printf("\n (a.1)  Synchronous reactance for rated
```

```
            current  at  If = %.2 f ,  Xs = %.2 f  Ohms  \n",If_scc,
        Xs_a1)
 98  printf("\n  (a.2)    Synchronous  reactance  for  rated
        per  phase  Voltage    at  v  = %.f ,  Xs = %.2 f  Ohms  \n
        ",v,Xs_a2)
 99  printf("\n For  Case  (b.1)  0.8  pf  Lagging  \n   Induced
         EMF  per  phase  ,  EMF = %.2 f  V  \n",E_b1)
100  printf("\n Percenatge  Regulation ,  R = %.2 f
        Percenatge  \n",r_b1)
101  printf("\n Power  angle = %.2 f  degree  \n",del_b1)
102  printf("\n For  Case  (b.2)  0.8  pf  Leading  \n   Induced
         EMF  per  phase ,  EMF = %.2 f  V  \n",E_b2)
103  printf("\n Percenatge  Regulation ,  R = %.2 f
        Percenatge  \n",r_b2)
104  printf("\n Power  angle = %.2 f  degree  \n",del_b2)
105  printf("\n For  Case  (b.3)  Unity  pf  Lagging  \n
        Induced  EMF  per  phase ,  EMF = %.2 f  V  \n",E_b3)
106  printf("\n Percenatge  Regulation ,  R = %.2 f
        Percenatge  \n",r_b3)
107  printf("\n Power  angle = %.2 f  degree  \n",del_b3)
108  printf("\n For  Case  (b.4)  ZPF  Lagging  \n   Induced
        EMF  per  phase ,  EMF = %.2 f  V\n",E_b4)
109  printf("\n Percenatge  Regulation ,  R = %.2 f
        Percenatge  \n",r_b4)
110  printf("\n Power  angle = %.1 f  degree  \n",del_b4)
111  printf("\n For  Case  (b.5)  ZPF  Leading  \n   Induced
        EMF  per  phase ,  EMF = %.2 f  V  \n",E_b5)
112  printf("\n Percenatge  Regulation ,  R = %.2 f
        Percenatge  \n",r_b5)
113  printf("\n Power  angle = %.2 f  degree  \n\n",del_b5)
114  disp(" Calculated  Answer  in  Tabular  Column")
115  printf("\n    Power  Factor                      0.8  Lag
          0.8  Lead          1.0           ZPF  Lag
        ZPF  Lead  \n")
116  printf("\n Open  circuit  EMF  (V)          %.2 f
            %.2 f            %.2 f          %.2 f           %.2 f
        \n",E_b1,E_b2,E_b3,E_b4,E_b5)
117  printf("\n Percenatge  Regulation            %.2 f
```

```
                %.2 f              %.2 f.          %.2 f              %
        .2 f \n",r_b1,r_b2,r_b3,r_b4,r_b5)
118 printf(" \n  Power  angle                        %.2 f
                %.2 f              %.2 f.          %.1 f
        %.2 f \n",del_b1,del_b2,del_b3,del_b4,del_b5)
```

Scilab code Exa 6.6 To find open circuit EMF in each cases

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  6  :  SYNCHRONOUS  MACHINES
8
9  // EXAMPLE  :  6.6
10
11 clear ; clc ; close ; // Clear  the  work  space  and
       console
12
13
14 // GIVEN DATA
15
16 printf(" \n EXAMPLE :  6.4  ( Data  is  same  as  Exaple
       6.4  ):  \n\n             Given  Data  \n");
17 printf(" \n  Voc(v)   215        284         320           380
           400          422          452          472          488
           508          520          532          540          552
           560  \n");
18 printf(" \n  If(A)       6.5          8           9           10
           11          12          14          15          16
           17          18          19          20          22
           24  \n\n");
19 m = 3;                              // Total Number of
```

213

```
        phase  in  Induction  Motor
20  p = 6;                             // Total  number  of
        Poles  of  Induction  Motor
21  V = 400;                           // Operating  voltage
        of  the  Induction  motor  in  Volts
22  I = 13.5;                          // Operating  current
        of  the  Induction  motor  in  Amphere
23  N = 1000;                          // speed  of  the
        Induction  motor  in  RPM
24  Ia_scc = 13.5;                     // SCC  test  Armature
        current  in  Amphere  at  If = 9.5  A
25  If_scc = 9.5;                      // SCC  test  field
        Rated  current  in  Amphere
26  Ia_zpf = 13.5;                     // ZPF  test  Armature
        current  in  Amphere  at  If = 24  A
27  If_zpf = 24;                       // ZPF  test  field
        Rated  current  in  Amphere
28
29
30  // CALCULATIONS
31  // Some  of  the  data  obtained  from  OCC  and  SCC  test
        Graph  or  Pottier  triangle  in  Figure6.15  &  Page  no
        :-386
32  Ra = 1.0;                          //
        Armature  resistance  in  Ohms
33  v = V/sqrt(3);                     // Rated
        phase  voltage  in  Volts
34
35
36  // For  Case  (a)  0.8  pf  Lagging
37
38  pfa_a = acosd(0.8);

        // Power  factor  angle  in  degree
39  E_a = v+(Ia_scc*(cosd(pfa_a)-%i*sind(pfa_a))*Ra);
                            // Induced  Voltage  in
        Volts
40  R1_a = 11.8;  A_a = 9.50;
```

214

```
      //From OCC the field current required for E_a (
      Should be in Line-line Voltage) E_a = 419.05V
      will get R1_a & A_a value Respectively from SCC (
      Figure6.15 & Page no:-386)
41 angle_a = 124.95;

      // Angle between R1_a & A_a (Figure6.21a & Page
      no:-400) = 90'-1.92'+36.87' = 124.95'
42 F_a = sqrt((R1_a^2)+(A_a^2)-(2*R1_a*A_a*cosd(angle_a
      )));                     // From phasor diagram in
      figure 6.21(a) & Page no:-400 the neccessary
      field excitation in Amphere
43 Eo_a = 538;

      // Corresponding to field current F_a = 18.94 A
      the open circuit EMF from OCC is 538 V (Figure6
      .15 & Page no:-386)
44 r_a = 100*((Eo_a-V)/V);

      // Percentage regulation
45
46
47 // For Case (b) 0.8 pf Leading
48
49 pfa_b = acosd(0.8);

      // Power factor angle in degree
50 E_b = v+(Ia_scc*(cosd(pfa_b)+%i*sind(pfa_b))*Ra);
                                // Induced Voltage in
      Volts
51 R1_b = 11.80; A_b = 9.50;

      //From OCC the field current required for E_b (
      Should be in Line-line Voltage) E_b = 419.10V
      will get R1_b & A_b value Respectively from SCC (
      Figure6.15 & Page no:-386)
52 angle_b = 55.07;
```

```
        // Angle between R1_b & A_b ( Figure6.21b & Page
        no:-400) = 90'-1.92'-36.87' = 55.07'
53  F_b = sqrt((R1_b^2)+(A_b^2)-(2*R1_b*A_b*cosd(angle_b
        )));                      // From phasor diagram in
        figure 6.21(b) & Page no:-400 the neccessary
        field excitation in Amphere
54  Eo_b = 382;

        // Corresponding to field current F_b = 10.10 A
        the open circuit EMF from OCC is 382 V ( Figure6
        .15 & Page no:-386)
55  r_b = 100*((Eo_b-V)/V);

        // Percentage regulation
56
57  // For Case (c) Unity pf
58
59  pfa_c = acosd(1);

        // Power factor angle in degree
60  E_c = v+(Ia_scc*(cosd(pfa_c)+%i*sind(pfa_c))*Ra)
                                // Induced Voltage in
        Volts
61  R1_c = 12.10; A_c = 9.50;
                                                      //
        From OCC the field current required for E_c (
        Should be in Line-line Voltage) E_c = 423.50V
        will get R1_c & A_c value Respectively from SCC (
        Figure6.15 & Page no:-386)
62  angle_c = 90;

        // Angle between R1_a & A_a ( Figure6.21a & Page
        no:-400) = 90'
63  F_c = sqrt((R1_c^2)+(A_c^2)-(2*R1_c*A_c*cosd(angle_c
        )));                      // From phasor diagram in
        figure 6.21(c) & Page no:-400 the neccessary
        field excitation in Amphere
```

```
64  Eo_c = 480;

        // Corresponding to field current F_c = 15.38 A
        the open circuit EMF from OCC is 538 V (Figure6
        .15 & Page no:-386)
65  r_c = 100*((Eo_c-V)/V);

        // Percentage regulation
66
67
68  // For Case (d) ZPF Lagging
69
70  pfa_d = acosd(0.0);

        // Power factor angle in degree
71  E_d = v+(Ia_scc*(cosd(pfa_d)-%i*sind(pfa_d))*Ra)
                                // Induced Voltage in
        Volts
72  R1_d = 11.20; A_d = 9.50;
                                                        //
        From OCC the field current required for E_d (
        Should be in Line-line Voltage) E_d = 400.80V
        will get R1_d & A_d value Respectively from SCC (
        Figure6.15 & Page no:-386)
73  angle_d = 179.40;

        // Angle between R1_d & A_d = 90'-0.6'+90' =
        179.40'
74  F_d = sqrt((R1_d^2)+(A_d^2)-(2*R1_d*A_d*cosd(angle_d
        )));                        // From phasor diagram the
        neccessary field excitation in Amphere
75  Eo_d = 545;

        // Corresponding to field current F_d = 18.12 A
        the open circuit EMF from OCC is 545 V (Figure6
        .15 & Page no:-386)
76  r_d = 100*((Eo_d-V)/V);
```

```scilab
     // Percentage regulation
77
78 // For Case (d) ZPF Lagging
79
80 pfa_e = acosd(0.0);

     // Power factor angle in degree
81 E_e = v+(Ia_scc*(cosd(pfa_e)+%i*sind(pfa_e))*Ra)
                              // Induced Voltage in
     Volts
82 R1_e = 11.20; A_e = 9.50;
                                                   //
     From OCC the field current required for E_e (
     Should be in Line-line Voltage) E_d = 400.80V
     will get R1_e & A_e value Respectively from SCC (
     Figure6.15 & Page no:-386)
83 angle_e = 0.60;

     // Angle between R1_e & A_e = 90'+0.6'-90' =
     0.60'
84 F_e = sqrt((R1_e^2)+(A_e^2)-(2*R1_e*A_e*cosd(angle_e
     )));                       // From phasor diagram the
     neccessary field excitation in Amphere
85 Eo_e = 63;

     // Corresponding to field current F_e = 1.70 A
     the open circuit EMF from OCC is 545 V (Figure6
     .15 & Page no:-386)
86 r_e = 100*((Eo_e-V)/V);

     // Percentage regulation
87
88
89
90 // DISPLAY RESULTS
91
92 disp(" SOLUTION :-");
93 printf("\n For Case (a) 0.8 pf Lagging \n  Open
```

```
          circuit EMF, EMF = %.f V \n",Eo_a)
94 printf("\n Percenatge Regulation , R = %.2f
          Percenatge \n",r_a)
95 printf("\n For Case (b) 0.8 pf Leading \n  Open
          circuit EMF, EMF = %.f V \n",Eo_b)
96 printf("\n Percenatge Regulation , R = %.2f
          Percenatge \n",r_b)
97 printf("\n For Case (c) Unity pf Lagging \n  Open
          circuit EMF, EMF = %.f V \n",Eo_c)
98 printf("\n Percenatge Regulation , R = %.f Percenatge
          \n",r_c)
99 printf("\n For Case (d) ZPF Lagging \n  Open circuit
          EMF, EMF = %.f V\n",Eo_d)
100 printf("\n Percenatge Regulation , R = %.2f
          Percenatge \n",r_d)
101 printf("\n For Case (e) ZPF Leading \n  Open circuit
          EMF, EMF = %.f V \n",Eo_e)
102 printf("\n Percenatge Regulation , R = %.2f
          Percenatge \n\n",r_e)
103 disp(" Calculated Answer in Tabular Column")
104 printf("\n    Power Factor                    0.8  Lag
          0.8  Lead          1.0        ZPF  Lag        ZPF
      Lead \n")
105 printf("\n Open circuit EMF (V)            %.f
              %.f            %.f            %.f            %
      .f \n",Eo_a,Eo_b,Eo_c,Eo_d,Eo_e)
106 printf("\n Percenatge Regulation            %.2f
              %.2f            %.f        %.2f            %.2f
      \n",r_a,r_b,r_c,r_d,r_e)
```

Scilab code Exa 6.7 To find open circuit EMF in each cases

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
```

```scilab
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.7
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 printf(" \n EXAMPLE : 6.7 ( Data as same as Example
       6.4 ) : \n\n           Given Data \n");
17 printf(" \n Voc(v)   215        284        320        380
              400         422        452        472        488
              508         520        532        540        552
              560 \n");
18 printf(" \n If(A)      6.5        8          9          10
              11          12         14         15         16
              17          18         19         20         22
              24 \n\n");
19 m = 3;                          // Total Number of
       phase in Induction Motor
20 p = 6;                          // Total number of
       Poles of Induction Motor
21 V = 400;                        // Operating voltage
       of the Induction motor in Volts
22 I = 13.5;                       // Operating current
       of the Induction motor in Amphere
23 N = 1000;                       // speed of the
       Induction motor in RPM
24 Ia_scc = 13.5;                  // SCC test Armature
       current in Amphere at If = 9.5 A
25 If_scc = 9.5;                   // SCC test field
       Rated current in Amphere
26 Ia_zpf = 13.5;                  // ZPF test Armature
```

220

```
         current in Amphere at If = 24 A
27  If_zpf = 24;                          // ZPF test field
         Rated current in Amphere
28
29
30  // CALCULATIONS
31  // Some of the data obtained from OCC and SCC test
         Graph or Pottier triangle in Figure6.15 & Page no
         :−386
32  Ra = 1.0;                                          //
         Armature resistance in Ohms
33  BC = 120;                                          // Open
         circuit Voltage in Volts obtained from OCC and
         SCC test Graph or Pottier triangle Figure6.15 &
         Page no:−386
34  Xl = BC/(sqrt(3)*Ia_scc);                    // Per
         phase leakage reactance in Ohms for this
         referring to example6.4 & page no:− 386
35
36  // For Case (a) 0.8 pf Lagging
37
38  pfa_a = acosd(0.8);

         // Power factor angle in degree
39  Er_a = (V/sqrt(3))+(Ia_scc*(cosd(pfa_a)-%i*sind(
         pfa_a))*(Ra+%i*Xl));        // Induced Voltage in
         Volts
40  R_a = 9.8; A_a = 9.5;

         //From OCC the field current required for Er_a (
         Should be in Line−line Voltage) Er_a = 479.60V
         will get R_a & A_a value Respectively from SCC (
         Figure6.15 & Page no:−386)
41  angle_a = 126.87;

         // Angle between R_a & A_a (Figure6.22(a) & Page
         no:−403) = 90'+36.87' = 126.87'
42  F_a = sqrt((R_a^2)+(A_a^2)-(2*R_a*A_a*cosd(angle_a))
```

```
      );                          // From  phasor  diagram  in
      figure  6.22( a )  &  Page  no:−403  the  neccessary
      field  excitation  in  Amphere
43 Eo_a = 560;

      // Corresponding  to  field  current  (  OF'=OF+FF' ) ,
      F_a  =  17.28  +  6.2  =  23.46  A  the  open  circuit  EMF
      from  OCC  is  560  V  ( Figure6.15  &  Page  no:−386)
44 r_a = 100*((Eo_a-V)/V);

      // Percentage  regulation
45
46
47 // For  Case  (b)  0.8  pf  Leading
48
49 pfa_b = acosd(0.8);

      // Power  factor  angle  in  degree
50 Er_b = (V/sqrt(3))+(Ia_scc*(cosd(pfa_b)+%i*sind(
      pfa_b))*(Ra+%i*Xl));        // Induced  Voltage  in
      Volts
51 R_b = 9.8; A_b = 9.5;

      //From  OCC  the  field  current  required  for  Er_b  (
      Should  be  in  Line−line  Voltage )  Er_b  =  363.90  V
      will  get  R_b  &  A_b  value  Respectively  from  SCC  (
      Figure6.15  &  Page  no:−386)
52 angle_b = 53.13;

      // Angle  between  R_b2  &  A_b2  ( Figure6.22b  &  Page
      no:−403)  =  90'−36.87'  =  53.13'
53 F_b = sqrt((R_b^2)+(A_b^2)-(2*R_b*A_b*cosd(angle_b))
      );                          // From  phasor  diagram  in
      figure  6.22( b )  &  Page  no:−403  the  neccessary
      field  excitation  in  Amphere
54 Eo_b = 380;

      // Corresponding  to  field  current  (  OF'=OF+FF' )
```

```
          F_b = 8.62+1.5=10.12 A the open circuit EMF from
          OCC is 380 V ( Figure6.15 & Page no:−386)
55  r_b = 100*((Eo_b-V)/V);

          // Percentage regulation
56

57

58  // For Case (c) Unity pf Leading

59

60  pfa_c = acosd (1.0) ;

          // Power factor angle in degree
61  Er_c = (V/sqrt(3))+(Ia_scc*(cosd(pfa_c)-%i*sind(
          pfa_c))*(Ra+%i*Xl));          // Induced Voltage in
          Volts
62  R_c = 9.8; A_c = 9.5;

          //From OCC the field current required for Er_c (
          Should be in Line−line Voltage) Er_c = 440.11 V
          will get R_c & A_c value Respectively from SCC (
          Figure6.15 & Page no:−386)
63  angle_c = 90;

          // Angle between R_c & A_c ( Figure6.22c & Page no
          :−403) = 90' = 90'
64  F_c = sqrt((R_c^2)+(A_c^2)-(2*R_c*A_c*cosd(angle_c))
          );                          // From phasor diagram in
          figure 6.22(c) & Page no:−403 the neccessary
          field excitation in Amphere
65  Eo_c = 510;

          // Corresponding to field current ( OF'=OF+FF')
          F_c = 13.65+3.0=16.65A the open circuit EMF from
          OCC is 510 V ( Figure6.15 & Page no:−386)
66  r_c = 100*((Eo_c-V)/V);

          // Percentage regulation
67
```

```
68
69  // For Case (d) ZPF Lagging
70
71  pfa_d = acosd(0);

        // Power factor angle in degree
72  Er_d = (V/sqrt(3))+(Ia_scc*(cosd(pfa_d)-%i*sind(
        pfa_d))*(Ra+%i*Xl));        // Induced Voltage in
        Volts
73  R_d = 9.8; A_d = 9.5;

        //From OCC the field current required for Er_d (
        Should be in Line-line Voltage) Er_d = 570.20 V
        will get R_d & A_d value Respectively from SCC (
        Figure6.15 & Page no:-386)
74  angle_d = 180.0;

        // Angle between R_d & A_d = 90'+90' = 180'
75  F_d = sqrt((R_d^2)+(A_d^2)-(2*R_d*A_d*cosd(angle_d))
        );                    // The neccessary field
        excitation in Amphere
76  Eo_d = 600;

        // Corresponding to field current ( OF'=OF+FF')
        F_d = 19.3+16=35.30 A the open circuit EMF from
        OCC is 525 V (Figure6.15 & Page no:-386)
77  r_d = 100*((Eo_d-V)/V);

        // Percentage regulation
78
79
80  // For Case (e) ZPF Lagging
81
82  pfa_e = acosd(0);

        // Power factor angle in degree
83  Er_e = (V/sqrt(3))+(Ia_scc*(cosd(pfa_e)+%i*sind(
        pfa_e))*(Ra+%i*Xl));        // Induced Voltage in
```

```
        Volts
84 R_e = 9.8; A_e = 9.50;

    //From OCC the field current required for Er_e (
       Should be in Line−line Voltage) Er_e = 281.10 V
       will get R_e & A_e value Respectively from SCC (
       Figure6.15 & Page no:−386)
85 angle_e = 0.0;

    // Angle between R_e & A_e = 90'−90' = 0.0'
86 F_e = sqrt((R_e^2)+(A_e^2)-(2*R_e*A_e*cosd(angle_e))
       );                        // The neccessary field
       excitation in Amphere
87 Eo_e = 5;

    // Corresponding to field current ( OF'=OF+FF')
       F_e = 0.0+0.30=0.30 A the open circuit EMF from
       OCC is 5 V (Figure6.15 & Page no:−386)
88 r_e = 100*((Eo_e-V)/V);

    // Percentage regulation
89
90
91 // DISPLAY RESULTS
92
93 disp(" SOLUTION :−");
94 printf("\n  Per phase leakage reactance , Xl = %.2 f
       Ohms \n",Xl)
95 printf("\n For Case (a) 0.8 pf Lagging \n  Open
       circuit EMF, EMF = %. f  V  \n",Eo_a)
96 printf("\n Percenatge Regulation , R = %. f Percenatge
       \n",r_a)
97 printf("\n For Case (b) 0.8 pf Leading \n  Open
       circuit EMF, EMF = %. f  V  \n",Eo_b)
98 printf("\n Percenatge Regulation , R = %. f Percenatge
       \n",r_b)
99 printf("\n For Case (c) Unity pf Lagging \n  Open
       circuit EMF, EMF = %. f  V  \n",Eo_c)
```

```
100  printf("\n Percenatge Regulation , R = %.f Percenatge
         \n",r_c)
101  printf("\n For Case (d) ZPF Lagging \n  Open circuit
         EMF, EMF = %.f V\n",Eo_d)
102  printf("\n Percenatge Regulation , R = %.f Percenatge
         \n",r_d)
103  printf("\n For Case (e) ZPF Leading \n  Open circuit
         EMF, EMF = %.f V \n",Eo_e)
104  printf("\n Percenatge Regulation , R = %.2f
         Percenatge \n\n",r_e)
105  disp(" Calculated Answer in Tabular Column")
106  printf("\n    Power Factor                          0.8 Lag
             0.8 Lead           1.0        ZPF Lag        ZPF
         Lead \n")
107  printf("\n Open circuit EMF (V)              %.f
                 %.f             %.f        %.f             %
         .f \n",Eo_a,Eo_b,Eo_c,Eo_d,Eo_e)
108  printf("\n Percenatge Regulation              %.f
                 %.f             %.1f        %.f             %
         .2f \n",r_a,r_b,r_c,r_d,r_e)
```

Scilab code Exa 6.9 To find induced EMF power angle and percent regulation

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.9
10
11  clear ; clc ; close ; // Clear the work space and
```

```
        console
12
13
14  // GIVEN DATA
15
16  printf(" \n EXAMPLE : 6.9 : \n\n                Given Data
       \n");
17  printf(" \n Voc(kV)    10        10.80        11.50
       12.10           12.60           13        14          14.50
            14.80 \n");
18  printf(" \n If(A)      175        200          225           250
                275          300          400          450
       500 \n\n");
19  p = 6;                                  // Total number of
       Poles of Alternator
20  V = 11*10^3;                            // Operating voltage
       of the Alternator in Volts
21  N = 1500;                               // speed of the
       Alternator in RPM
22  Ia_scc = 2099;                          // SCC test Armature
       current in Amphere at If = 200 A
23  If_scc = 200;                           // SCC test field
       Rated current in Amphere
24  Ia_pt = 2099;                           // Pottier test
       Armature current in Amphere at If = 450 A
25  If_pt = 450;                            // Pottier test field
        Rated current in Amphere
26  VA = 40*10^6;                           // VA rating of the
       Alternator in Volts-Amphere
27  f = 50;                                 // Operating
       Frequency of the Alternator in Hertz
28  pf = 0.8;                               // Power factor (
       lagging)
29
30  // CALCULATIONS
31  // Some of the data obtained from OCC and SCC test
       Graph or Pottier triangle in Figure6.24 & Page no
       :-407
```

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```
32
33  v = V/sqrt(3);

        // Rated phase Voltage in Volts
34  I = VA/(sqrt(3)*V);
                                                    //
        Full-load phase current in Amphere
35  Xl = 0.4481;

        // Leakage reactance in Ohms From OCC and SCC
        test Graph or Pottier triangle in Figure6.24 &
        Page no:-407
36
37
38  // For Case(a) General Method
39
40  pfa_a = acosd(pf);

        // Power factor angle in degree
41  Er_a = (V/sqrt(3))+(Ia_scc*(cosd(pfa_a)-%i*sind(
        pfa_a))*Xl);               // Induced Voltage in
        Volts
42  R_a = 208.4; A_a = 200;

        //From OCC the field current required for Er_a (
        Should be in Line-line Voltage) Er_a = 11043.66 V
         will get R_a & A_a value Respectively from SCC (
        Figure6.24 & Page no:-407)
43  angle_a = 131.93;

        // Angle between R_a & A_a (Figure6.25(a) & Page
        no:-408) = 90'+5.06'+36.87' = 131.93'
44  F_a = sqrt((R_a^2)+(A_a^2)-(2*R_a*A_a*cosd(angle_a))
        );                        // From phasor diagram in
        figure  6.25(a) & Page no:-408 the neccessary
        field excitation in Amphere
45  Eo_a = 13720;
```

```
          // Corresponding to field current, F_a = 373 A
          the open circuit EMF from OCC is 560 V (Figure6
          .15 & Page no:-386)
46  r_a = 100*((Eo_a-V)/V);

          // Percentage regulation
47
48
49  // For Case (b) ASA Method
50
51  pfa_b = acosd(pf);

          // Power factor angle in degree
52  Er_b = (V/sqrt(3))+Ia_scc*(cosd(pfa_b)-%i*sind(pfa_b
          ))*Xl;                    // Induced Voltage in Volts
53  R_b = 160; A_b = 200;

          //From OCC the field current required for Er_b (
          Should be in Line-line Voltage) Er_b = 11043.66 V
           will get R_b & A_b value Respectively from SCC (
          Figure6.24 & Page no:-407)
54  angle_b = 126.87;

          // Angle between R_b2 & A_b2 (Figure6.22b & Page
          no:-403) = 90'+36.87' = 126.87'
55  F_b = sqrt((R_b^2)+(A_b^2)-(2*R_b*A_b*cosd(angle_b))
          );                        // From phasor diagram in
          figure 6.25(b) & Page no:-408 the neccessary
          field excitation in Amphere
56  Eo_b = 13660;

          // Corresponding to field current ( OF'=OF+FF')
          F_b = 337.88+15.38=337.88  A the open circuit EMF
           from OCC is 13660 V (Figure6.15 & Page no:-386)
57  r_b = 100*((Eo_b-V)/V);

          // Percentage regulation
58
```

```
59
60  // DISPLAY RESULTS
61
62  disp(" SOLUTION :-");
63  printf("\n For Case (a) General(ZPF) Method \n
        Induced EMF, EMF = %.f < %.2f V \n",abs(Er_a),
        atand(imag(Er_a),real(Er_a)))
64  printf("\n Percenatge Regulation, R = %.2f
        Percenatge \n",r_a)
65  printf("\n For Case (b) ASA Method \n  Induced EMF,
        EMF = %.f < %.2f V \n",abs(Er_b),atand(imag(Er_b)
        ,real(Er_b)))
66  printf("\n Percenatge Regulation, R = %.2f
        Percenatge \n",r_b)
67  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
68  printf("\n        WRONGLY PRINTED ANSWERS ARE :- For
        Case (a) General(ZPF) Method (a) Induced EMF =
        6376<-5.07 degree instead of %.f < %.2f \n ",abs(
        Er_a),atand(imag(Er_a),real(Er_a)))
69  printf("\n                                    For
        Case (b) ASA Method        (a) Induced EMF =
        6376<-5.07 degree instead of %.f < %.2f \n\n ",
        abs(Er_b),atand(imag(Er_b),real(Er_b)))
70  printf(" CALCULATION OF THE POWER ANGLE IS NOT
        CALCULATED IN THE TEXT BOOK FOR THIS PROBLEM\n ")
71  printf("\n INDUCED EMF AND PERCENTAGE REGULATION IS
        APPROXIMATED VALUE BECACUSE IN THE TEXT BOOK,
        CALCULATED INDUCED EMF IS WRONGLY PRINTED")
```

Scilab code Exa 6.10 To find field current

```
1
2  // ELECTRICAL MACHINES
```

```scilab
3  // R.K.Srivastava
4  //  First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  6  :  SYNCHRONOUS  MACHINES
8
9  // EXAMPLE  :  6.10
10
11 clear ; clc ; close ; // Clear  the  work  space  and
       console
12
13
14 // GIVEN DATA
15
16 m = 3;                            // Total  Number  of
       Phase  in  Alternator
17 p = 2;                            // Total  number  of
       Poles  of  Alternator
18 V = 11*10^3;                      // Operating  voltage
       of  the  Alternator  in  Volts
19 VA = 10*10^6;                     // VA rating  of  the
       Alternator  in  Volts-Amphere
20 f = 50;                           // Operating
       Frequency  of  the  alternator  in  Hertz
21 pf = 0.8;                         // Power  factor  (
       lagging )
22 Vf = 12*10^3;                     // Operating  field
       voltage  of  the  Alternator  in  Volts
23 If = 160;                         // Field  Current  in
       Amphere
24 Ra = 0.05;                        // Armature
       Resistance  per  phase  in  Ohms
25 Xs = 1.5;                         // Winding  leakage
       reactance  per  phase  in  Ohms
26 A = 150;                          // The  armature  MMF  at
       rated  current  is  equivalent  to  Field  Current  in
       Amphere
27
```

```
28
29  // CALCULATIONS
30
31  Vt = V/sqrt(3);
        // Rated per phase Voltage in Volts
32  Ia = VA/(sqrt(3)*V);
        // Rated Armature Current in Amphere
33  pfa = acosd(pf);
        // Power factor angle in degree
34  Er = Vt+Ia*(cosd(pfa)-%i*sind(pfa))*(Ra+%i*Xs);
        // Induced EMF in Volts
35  R_a = 90 + atand(imag(Er),real(Er));
        // Angle of R in Degree
36  R = 160 * exp( %i * (R_a) * %pi/180);
        // (Line-line Voltage) Er = 11902.40V will get R
        from Air gap Characteristics
37  A_n = A * exp( %i * (-pfa) * %pi/180);
38  F = R - A_n;
        // Field Current required to produce the
        excitation EMF in Amphere
39
40
41  // DISPLAY RESULTS
42
43  disp("EXAMPLE : 6.10: SOLUTION :-");
44  printf("\n (a) Field Current required to produce the
        excitation EMF, F = %.2f A \n",abs(F))
```

Scilab code Exa 6.11 To find leakage and synchronous reactance and field current

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
```

```
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.11
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 printf("\n EXAMPLE : 6.11 : \n\n          Given Data
      \n");
17 printf("\n Voc( V)    12       13        13.8         14.5
           15.1   \n");
18 printf("\n If(A)      175       200      225          250
           275   \n\n");
19 V = 11*10^3;                        // Operating voltage
      of the Synchronous generator in Volts
20 VA = 50*10^6;                       // VA rating of the
      Synchronous generator in Volts-Amphere
21 f = 50;                             // Operating
      Frequency of the Synchronous generator in Hertz
22 N = 1500;                           // Speed of the
      Synchronous generator in RPM
23 If_scc = 200;                       // SCC test field
      Rated current in Amphere at rated Short circuit
      current
24 If_zpf = 400;                       // ZPF test field
      Rated current in Amphere at rated voltage and
      rated current
25 pf = 0.8;                           // Power factor (
      lagging )
26
27
28 // CALCULATIONS
29 // Some of the data obtained from OCC and SCC test
```

```scilab
         Graph or Pottier triangle in Figure6.30 & Page no
         :-413
30
31  Vt = V/sqrt(3);
         // Rated per phase Voltage in Volts
32  Ia = VA/(sqrt(3)*V);
         // Rated Armature Current in Amphere
33  pfa = acosd(pf);
         // Power factor angle in degree
34  O = 13000;
         // Open circuit Voltage in Volts obtained from
         OCC and SCC test Graph or Pottier triangle
         Figure6.30 & Page no:-413
35  Xs = O/(sqrt(3)*Ia);
         // Synchronous reactance per phase in Ohms
36  BC = 4000;
         // Open circuit Voltage in Volts obtained from
         OCC and SCC test Graph or Pottier triangle
         Figure6.30 & Page no:-413
37  Xl = BC/(sqrt(3)*Ia );
         // Per phase leakage reactance in Ohms
38
39  // For Case (a) General (ZPF) Method
40
41  Er_a = Vt+Ia*(cosd(pfa)-%i*sind(pfa))*(%i*Xl);
                                    // Induced EMF in
         Volts
42  R_a = 220; A_a = 200;

         //From OCC the field current required for Er_a (
         Should be in Line-line Voltage) Er_a = 13776V
         will get R_a & A_a value Respectively from SCC (
         Figure6.30 & Page no:-403)
43  angle_a = 140.3;

         // Angle between R_a & A_a = 90'+13.43'+36.87' =
         140.3'
44  F_a = sqrt((R_a^2)+(A_a^2)-(2*R_a*A_a*cosd(angle_a))
```

```
    );                              // From  phasor  diagram  in
       figure  6.16(a) &  Page  no:−388  the  neccessary
       field  excitation  in  Amphere
45  Eo_a = 20000;

       //  Corresponding  to  field  current  F_a = 470.90 A
       the  open  circuit  EMF  from  OCC  is  20000  V ( Figure6
       .30 &  Page  no:−413)
46  r_a = 100*((Eo_a-V)/V);

       //  Percentage  regulation
47
48
49  //  For  Case(b)  EMF  Method
50
51  Er_b = Vt+Ia*(cosd(pfa)-%i*sind(pfa))*(%i*Xs);
                                    //  Induced  Voltage  in
       Volts
52  F_b = 500;

       //From  OCC  the  field  current  required  for  Er_b (
       Should  be  in  Line−line  Voltage)  Er_b = 21404  V
       will  get  500A  from  SCC ( Figure6.15 &  Page  no
       :−386)
53
54  //  For  Case  (c)  MMF  Method
55
56  Er_c = Vt+Ia*(cosd(pfa)-%i*sind(pfa))*0;
                                    //  Induced
       Voltage  in  Volts ( Zero  is  multipied  because
       Armature  reistance  is  zero ( not  mentioned))
57  R_c = 160;  A_c = 200;

       //From  OCC  the  field  current  required  for  Er_c (
       Should  be  in  Line−line  Voltage)  Er_c = 11000  V
       will  get  R_c &  A_c  value  Respectively  from  SCC (
       Figure6.30 &  Page  no:−413)
58  angle_c = 126.27;
```

```
     // Angle between R_c & A_c = 90'-0'+36.87' =
     126.27' {can refer figure 6.21a at page no:-400}
59 F_c = sqrt((R_c^2)+(A_c^2)-(2*R_c*A_c*cosd(angle_c))
     );                          // From phasor diagram {can
      refer figure 6.21a at page no:-400} the
     neccessary field excitation in Amphere
60
61
62 // For Case (d) ASA Method
63
64 Er_d = Vt+Ia*(cosd(pfa)-%i*sind(pfa))*(%i*Xl);
                                 // Induced Voltage in
     Volts
65 R_d = 220; A_d = 200;

     //From OCC the field current required for Er_d (
     Should be in Line-line Voltage) Er_d = 13800 V
     will get R_d & A_d value Respectively from SCC (
     Figure6.30 & Page no:-413)
66 angle_d = 126.87;

     // Angle between R_d & A_d = 90'+36.87' =
     126.87'{can refer figure 6.22a at page no:-40}
67 F_d1 = sqrt((R_d^2)+(A_d^2)-(2*R_d*A_d*cosd(angle_d)
     ));                        // from Phasor diagram {can
      refer figure 6.2a at page no:-400 The neccessary
      field excitation in Amphere
68 F_d = F_d1 + 30;

     // from Phasor diagram {can refer figure 6.2a at
     page no:-400 The Total neccessary field
     excitation in Amphere
69
70
71 // DISPLAY RESULTS
72
73 disp(" SOLUTION :-");
```

```
74  printf("\n (a) Leakage Reactance, Xl = %.2f Ohms \n"
        ,Xl)
75  printf("\n (b) Synchronous Reactance, Xs = %.2f Ohms
        \n",Xs)
76  printf("\n For Case (a) General (ZPF) Method \n
        Field Current required for maintaing the rated
        terminal voltage for rated kVA rating at %.2f
        Lagging Power factor , F = %.2f A \n",pf,F_a)
77  printf("\n For Case (a) EMF Method \n Field Current
        required for maintaing the rated terminal voltage
         for rated kVA rating at %.2f Lagging Power
        factor , F = %.f A \n",pf,F_b)
78  printf("\n For Case (a) MMF Method \n Field Current
        required for maintaing the rated terminal voltage
         for rated kVA rating at %.2f Lagging Power
        factor , F = %.2f A \n",pf,F_c)
79  printf("\n For Case (a) ASA Method \n Field Current
        required for maintaing the rated terminal voltage
         for rated kVA rating at %.2f Lagging Power
        factor , F = %.f A \n",pf,F_d)
80  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
81  printf("\n        WRONGLY PRINTED ANSWERS ARE :− For
        Case (a) General (ZPF) Method \n (a) Field
        Current required for maintaining the rated
        terminal voltage for rated kVA rating at %.2f
        Lagging Power factor , F = 470.90 A instead of %
        .2f A \n",pf,F_a);
```

Scilab code Exa 6.12 To find leakage and synchronous reactance and field current

```
1
2  // ELECTRICAL MACHINES
```

```scilab
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.12
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16
17 printf("\n EXAMPLE : 6.12 : \n\n           Given Data
       \n");
18 printf("\n Voc(V)    175        250        280        300
              330        350        370        380 \n");
19 printf("\n If(A)     10         17         20         23
              30         38         50         60 \n");
20 printf("\n Vzpf(V)        -          -          -          0
              130        210        265        280 \n\n");
21 V = 433;                         // Operating voltage
       of the Alternator in Volts
22 N = 3000;                        // speed of the
       Alternator in RPM
23 VA = 20*10^3;                    // VA rating of the
       Alternator in Volts-Amphere
24 f = 50;                          // Operating
       Frequency of the Alternator in Hertz
25 pf = 0.8;                        // Power factor (
       lagging)
26
27
28 // CALCULATIONS
29 // Some of the data obtained from OCC and SCC test
       Graph or Pottier triangle in Figure6.35 & Page no
```

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```
        :−420
30
31  Vt = V/sqrt(3);
       // Rated per phase Voltage in Volts
32  Ia = VA/(sqrt(3)*V);
       // Rated Armature Current in Amphere
33  pfa = acosd(pf);
       // Power factor angle in degree
34  O = 298;
       // Open circuit Voltage in Volts obtained from
       OCC and SCC test Graph or Pottier triangle
       Figure6.30 & Page no:−413
35  Xs = O/(sqrt(3)*Ia);
       // Synchronous reactance per phase in Ohms
36  BC = 70;
       // Open circuit Voltage in Volts obtained from
       OCC and SCC test Graph or Pottier triangle
       Figure6.30 & Page no:−413
37  Xl = BC/(sqrt(3)*Ia );
       // Per phase leakage reactance in Ohms
38  E = Vt+Ia*(cosd(pfa)-%i*sind(pfa))*(%i*Xs);
       // Induced EMF in Volts using EMF Method
39  c = 380-60;
       // The open Voltage voltage is 694.50V (line−line
       ) its Obatained by extrapolation
40  y = 694.50;
       // The open Voltage voltage is 694.50V (line−line
       ) its Obatained by extrapolation
41  // Extrapolation Equation is y = (x*(380−370)
       /(60−50))*c
42  x = y - c;
       // The required field current in Amphere
43
44
45  // DISPLAY RESULTS
46
47  disp(" SOLUTION :−");
48  printf("\n (a) Leakage Reactance , Xl = %.2 f Ohms \n"
```

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```
      ,Xl)
49  printf(”\n (b) Synchronous Reactance, Xs = %.2f Ohms
       \n”,Xs)
50  printf(”\n (c) Field Current required for maintaing
       the rated terminal voltage for rated kVA rating
       at %.2f Lagging Power factor , F = %.2f A \n”,pf,
       x)
```

Scilab code Exa 6.13 To find induced EMF power angle and percent regulation

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.13
10
11  clear ; clc ; close ; // Clear the work space and
       console
12
13
14  // GIVEN DATA
15
16
17  V = 400;                        // Operating voltage
       of the Synchronous generator in Volts
18  VA = 60*10^3;                   // VA rating of the
       Synchronous generator in Volts−Amphere
19  f = 50;                         // Operating
       Frequency of the Synchronous generator in Hertz
20  xd = 1.5;                       // Direct axis
```

240

```
        reactances  in  Ohms
21  xq = 0.6;                           // Quadrature  axis
        reactances  in  Ohms
22
23
24  // CALCULATIONS
25
26  I = VA/(sqrt(3)*V);                          //
        Rated  current  in  Amphere
27  v = V/sqrt(3);                               //
        Rated  Phase  Votage  in  Volts
28
29  // For  Case  (a)  0.80  lagging  Power  factor  (Refer
        figure  6.36  page  no.  421)
30
31  pf_a = 0.8;

        // Power  factor
32  pfa_a = acosd(pf_a);
                                                 //
        Power  factor  angle  in  deg
33  pa_a = atand((I*xq*cosd(pfa_a))/(v+I*xq*sind(pfa_a))
        );            // Power  angle  in  deg
34  Iq_a = I*cosd(pfa_a+pa_a);
                                                 // Current
        in  Amphere
35  Id_a = I*sind(pfa_a+pa_a);
                                                 // Current
        in  Amphere
36  Eo_a = sqrt((v+Id_a*xd*cosd(pa_a)-Iq_a*xq*sind(pa_a)
        )^2 + (Id_a*xd*sind(pa_a)+Iq_a*xq*cosd(pa_a))^2);
                                                 //
        Induced  EMF  in  Volts
37  pr_a = ((Eo_a-v)/v)*100;
                                                 //
        Percentage  regulation
38
39  // For  Case  (b)  Unity  Power  factor  (Refer  figure
```

```
      6.37 page no. 422)
40
41 pf_b = 1.0;

      // Power factor
42 pfa_b= acosd(pf_b);
                                                            //
      Power factor angle in deg
43 pa_b = atand((I*xq*cosd(pfa_b))/(v+I*xq*sind(pfa_b))
      );          // Power angle in deg
44 Iq_b = I*cosd(pfa_b+pa_b);
45 Id_b = I*sind(pfa_b+pa_b);
46 Eo_b = sqrt((v+Id_b*xd*cosd(pa_b)-Iq_b*xq*sind(pa_b)
      )^2 + (Id_b*xd*sind(pa_b)+Iq_b*xq*cosd(pa_b))^2);
                                                            //
      Induced EMF in Volts
47 pr_b = ((Eo_b-v)/v)*100;
                                                      //
      Percentage regulation
48
49 // For Case (c) 0.80 lagging Power factor (Refer
      figure 6.36 page no. 421)
50
51 pf_c = 0.8;

      // Power factor
52 pfa_c = acosd(pf_c);
                                                      //
      Power factor angle in deg
53 pa_c = atand((I*xq*cosd(pfa_c))/(v-I*xq*sind(pfa_c))
      );          // Power angle in deg
54 Iq_c = I*cosd(pfa_c-pa_c);
55 Id_c = I*sind(pfa_c-pa_c);
56 Eo_c = sqrt((v-Id_c*xd*cosd(pa_c)-Iq_c*xq*sind(pa_c)
      )^2 + (-Id_c*xd*sind(pa_c)+Iq_c*xq*cosd(pa_c))^2)
      ;                                                    //
       Induced EMF in Volts
57 pr_c = ((Eo_c-v)/v)*100;
```

```
                                        //
      Percentage regulation
58
59
60  // DISPLAY RESULTS
61
62  disp("EXAMPLE : 6.13: SOLUTION :−");
63  printf("\n For Case (a) 0.80 lagging Power factor \n
        Induced EMF, EMF = %.2f V \n",Eo_a)
64  printf("\n Power angle = %.3f degree \n",pa_a)
65  printf("\n Percenatge Regulation , R = %.1f
      Percenatge \n",pr_a)
66  printf("\n For Case (b) Unity Power factor \n
      Induced EMF, EMF = %.2f V \n",Eo_b)
67  printf("\n Power angle = %.2f degree \n",pa_b)
68  printf("\n Percenatge Regulation , R = %.2f
      Percenatge \n",pr_b)
69  printf("\n For Case (c) 0.80 leading Power factor \n
        Induced EMF, EMF = %.2f V \n",Eo_c)
70  printf("\n Power angle = %.2f degree \n",pa_c)
71  printf("\n Percenatge Regulation , R = %.2f
      Percenatge \n",pr_c)
```

Scilab code Exa 6.14 To find induced EMF power angle and percent regulation

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.14
```

```
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16
17 v = 1.0;                                // Operating voltage
      of the Synchronous generator in pu
18 xd = 1.0;                               // Direct axis
      reactances in pu
19 xq = 0.5;                               // Quadrature axis
      reactances in pu
20 I = 1.0;                                // Rated current in
      pu
21
22
23 // CALCULATIONS
24
25 // For Case (a) 0.80 lagging Power factor (Refer
      figure 6.36 page no. 421)
26
27 pf_a = 0.8;

      // Power factor
28 pfa_a = acosd(pf_a);
                                                          //
      Power factor angle in deg
29 pa_a = atand((I*xq*cosd(pfa_a))/(v+I*xq*sind(pfa_a))
      );            // Power angle in deg
30 Iq_a = I*cosd(pfa_a+pa_a);
31 Id_a = I*sind(pfa_a+pa_a);
32 Eo_a = sqrt((v+Id_a*xd*cosd(pa_a)-Iq_a*xq*sind(pa_a)
      )^2 + (Id_a*xd*sind(pa_a)+Iq_a*xq*cosd(pa_a))^2);
                                                          //
      Induced EMF in Volts
33 pr_a = ((Eo_a-v)/v)*100;
```

```
                                                                 //
     Percentage  regulation
34
35  // For Case (b) Unity Power factor (Refer figure
     6.37 page no. 422)
36
37  pf_b = 1.0;

     // Power factor
38  pfa_b= acosd(pf_b);
                                                                 //
     Power factor angle in deg
39  pa_b = atand((I*xq*cosd(pfa_b))/(v+I*xq*sind(pfa_b))
     );            // Power angle in deg
40  Iq_b = I*cosd(pfa_b+pa_b);
41  Id_b = I*sind(pfa_b+pa_b);
42  Eo_b = sqrt((v+Id_b*xd*cosd(pa_b)-Iq_b*xq*sind(pa_b)
     )^2 + (Id_b*xd*sind(pa_b)+Iq_b*xq*cosd(pa_b))^2);
                                                                 //
     Induced EMF in Volts
43  pr_b = ((Eo_b-v)/v)*100;
                                                                 //
     Percentage  regulation
44
45  // For Case (c) 0.80 lagging Power factor (Refer
     figure 6.36 page no. 421)
46
47  pf_c = 0.8;

     // Power factor
48  pfa_c = acosd(pf_c);
                                                                 //
     Power factor angle in deg
49  pa_c = atand((I*xq*cosd(pfa_c))/(v-I*xq*sind(pfa_c))
     );             // Power angle in deg
50  Iq_c = I*cosd(pfa_c-pa_c);
51  Id_c = I*sind(pfa_c-pa_c);
52  Eo_c = sqrt((v-Id_c*xd*cosd(pa_c)-Iq_c*xq*sind(pa_c)
```

```
      )^2 + (-Id_c*xd*sind(pa_c)+Iq_c*xq*cosd(pa_c))^2)
      ;                                                 //
         Induced EMF in Volts
53 pr_c = ((Eo_c-v)/v)*100;
                                                         //
      Percentage regulation
54
55
56 // DISPLAY RESULTS
57
58 disp("EXAMPLE : 6.14: SOLUTION :-");
59 printf("\n For Case (a) 0.80 lagging Power factor \n
         Induced EMF, EMF = %.4f V \n",Eo_a)
60 printf("\n Power angle = %.1f degree \n",pa_a)
61 printf("\n Percenatge Regulation , R = %.2f
      Percenatge \n",pr_a)
62 printf("\n For Case (b) Unity Power factor \n
      Induced EMF, EMF = %.2f V \n",Eo_b)
63 printf("\n Power angle = %.2f degree \n",pa_b)
64 printf("\n Percenatge Regulation , R = %.2f
      Percenatge \n",pr_b)
65 printf("\n For Case (c) 0.80 leading Power factor \n
         Induced EMF, EMF = %.4f V \n",Eo_c)
66 printf("\n Power angle = %.2f degree \n",pa_c)
67 printf("\n Percenatge Regulation , R = %.2f
      Percenatge \n",pr_c)
```

Scilab code Exa 6.15 To find field current

```
1
2 // ELECTRICAL MACHINES
3 // R.K.Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
```

```scilab
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.15
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16
17 If = 1.25;                        // Given that rated
       voltage at air gap line for this field current in
        pu
18 IF = 0.75;                        // Rated current in
       SC test for this field current in pu
19 Ia = 1.0;                         // Rated current in
       Per unit
20 pf = 0.8;                         // Power factor
21 V = 1.0;                          // Rated Volatge in
       pu
22
23
24 // CALCULATIONS
25
26 pfa = acosd(pf);
                                              // Power
       factor angle in deg
27 Voc = (V*IF)/If;
                                              // Open
       circuit volatge in pu
28 xs = Voc/Ia;
                                                    //
       Syncronous reactance in pu
29 E = V + Ia*(cosd(pfa)-(%i)*sind(pfa))*(%i*xs);
                  // Induced EMF in pu
30 a = abs(E)*If;
31
```

```
32  // DISPLAY RESULTS
33
34  disp("EXAMPLE : 6.15: SOLUTION :−");
35  printf("\n Induced EMF, E = %.2f < %.2f pu \n ",abs(
        E),atand(imag(E),real(E)))
36  printf("\n The field current required for %.2f pu
        voltage on air gap line %.1f pu \n",abs(E),a)
```

Scilab code Exa 6.16 To find induced EMF power angle power and counter torque

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.16
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16
17  V = 440;                            // Operating voltage
        of the alternator in Volts
18  VA = 20*10^3;                       // VA rating of the
        alternator in Volts−Amphere
19  f = 50;                             // Operating
        Frequency of the alternator in Hertz
20  N = 3000;                           // Rotation of the
```

```
          alternator in RPM
21 Ra = 0.0;                              // Armature reistance
        in Ohms
22 xl = 0.6;                              // Armature
      reactances in Ohms
23 pf = 0.8;                              // Power factor
      lagging
24 pfa = acosd(pf);                        // ower factor angle
        in deg
25 p = (120*f)/N;                         // Number of poles
26 w = (2*%pi*f);                         //  Rotation speed in
        Radians per second
27 v = V/sqrt(3);                         // Rated phase
      voltage in Volts
28 I = VA/(sqrt(3)*V);                    // Rated curent in
      Amphere
29 If = I;                                // Given field
      current = armature current from SCC test in
      Amphere
30 E = 16*If;                             // Open-circuit EMF
      at field current in Volts given from Equation E =
       16If refer page no. 431
31 xs = E/(If*sqrt(3));                   // Synchronous
      reactance in Ohms
32 Eo = sqrt((v+I*xs*sind(pfa))^2 + (I*xs*cosd(pfa))^2)
     ;                // Induced EMF in Volts
33 pa = atand(193.98/399.49);
                                                   // From
      above equation Eo
34 pr = ((Eo-v)/v)*100;
                                                        //
      Percent regulation
35 P = (3*v*Eo*sind(pa))/(xs*1000);
                                          // Power inKilo-
      Watts
36 T = (P*1000)/w;

      // Torque devolped in Newton-meter
```

```
37
38
39  // DISPLAY RESULTS
40
41  disp("EXAMPLE : 6.16: SOLUTION :-");
42  printf("\n Induced EMF, EMF = %. f V \n",Eo)
43  printf("\n Power angle = %.2 f degree \n",pa)
44  printf("\n Power, P = %.3 f kW \n",P)
45  printf("\n Counter Torque, T = %.2 f N-m \n",T)
46  printf("\n\n      [ TEXT BOOK SOLUTION IS PRINTED
       WRONGLY ( I verified by manual calculation )]\n"
       );
47  printf("\n        WRONGLY PRINTED ANSWERS ARE :- \n (a
       ) Induced EMF, EMF = 471 V instead of %. f V \n",
       Eo)
48  printf("\n (b) Power angle = 18.05 degree instead of
        %.2 f degree \n",pa)
49  printf("\n (c) Power, P = 12.003 kV instead of %.3 f
       kW \n",P)
50  printf("\n (d) Counter Torque, T = 38.23 N-m instead
        of %.2 f N-m \n",T)
51  printf("\n From Calculation of the Induced EMF(E),
       rest all the Calculated values in the TEXT BOOK
       is WRONG because of the Induced EMF(E) value is
       WRONGLY calculated and the same used for the
       further Calculation part \n")
```

Scilab code Exa 6.17 To find line current pf power torque and excitation EMF and power angle at UPF

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
```

```
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.17
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16
17 V = 440;                              // Operating voltage
      of the Synchronous Motor in pu
18 E = 200;                              // Induced voltage in
       Volts
19 xs = 8.0;                            // Synchronous
      reactance in Ohms
20 f = 50;                              // Frequency in Hertz
21 pa = 36;                             // Power angle in
      degree
22
23
24 // CALCULATIONS
25
26 v = V/sqrt(3);                       // Rated phase
      voltage in Volts
27 ws = 2*%pi*f;                        // Synchronous speed
      in Radians per second
28 // To calculate the power factor angle refer page no
       438 n figure 6.50
29 // Since E*cos(delta) < v so Power factor is lagging
      , let power factor angle be theta from ohasor
      diagram figure 6.50:- page no. 438
30 // v = E*cos(delta) + I*xs*sin(theta), I*sin(theta)
      = (254-0.809*200)/8 = 11.525
31 // Similarly, E*sin(delta) = I*xs*cos(theta), I*cos(
      theta) = (200*0.59)8 = 14.70
```

```
32 // From above two equations, tan(theta) = 0.784
33 theta = -38.1;                                      //
      Power factor angle in degree (minus sign because
      of lagging)
34 pf = cosd(theta);                                   //
      Power factor lagging
35 I = 14.7/cosd(theta);                               //
      Line current in Amphere (I*cos(theta) = 14.7)
36 p = 3 * v * 14.7;                                   //
      Input to motor in watts ( p = 3*V*I*cos(theta), I
      *cos(theta) = 14.7)
37 P = (3*E*v*sind(pa))/(xs*1000);                     //
      Power in Kilo-watts
38 T = (P*1000)/ws;                                    //
      Torque in Newton-meter
39 // For Power factor unity
40 // let the current will be I2, thus 3*v*I2 = 3*v*I*
      cos(theta) , I2 = I*cos(theta) = 14.10 A
41 // let ecitation will be E2, thus v = E2*cos(delta2)
       and E2*sin(delta2) = I2*xs, E2*cos(delta2) = 254
       and E2*sin(delta2) = 117.60, by solving these
      two equations we get E2 = sqrt(254^2+117.6^2) =
      279.90 V and delta2 = atand(117.6/254) = 24.84
      degree
42 E2 = 279.90;
43 delta2 = 24.84;
44 P_1 = (3*v*E2*sind(delta2))/(xs*1000);
                        // Power in kilo-watts
45 T_1 = (P_1*1000)/ws;
                                          // Torque
      in Newton-meter
46
47
48 // DISPLAY RESULTS
49
50 disp("EXAMPLE : 6.17: SOLUTION :-");
51 printf("\n (a) Line current, I = %.2f A \n",I)
52 printf("\n (b) Power factor angle = %.1f degree \n",
```

```
        theta )
53  printf ( " \n  ( c )  Power  ,  P  =  %.3 f  kW  \n" , P )
54  printf ( " \n  ( d )  Torque  ,  T  =  %.2 f  N−m  \n" , T )
55  printf ( " \n  ( e )  Power  factor  =  %.2 f  lagging  \n" , pf )
56  printf ( " \n  To  make  the  Power  factor  to  UNITY
        requirements  are:−  \n  ( a )  Excitation  EMF,  E  =  %.2
        f  V  \n" , E2 )
57  printf ( " \n  ( b )  Power  angle  =  %.2 f  degree  \n" , delta2 )
58  printf ( " \n  ( c )  Power  ,  P  =  %.3 f  kW  \n" , P_1 )
59  printf ( " \n  ( d )  Torque  ,  T  =  %.2 f  N−m  \n" , T_1 )
```

Scilab code Exa 6.18 To find excitation EMF per phase line current pf power torque

```
1
2  //  ELECTRICAL  MACHINES
3  //  R.K. Srivastava
4  //  First  Impression  2011
5  //  CENGAGE  LEARNING  INDIA  PVT.  LTD
6  //  CHAPTER  :  6  :  SYNCHRONOUS  MACHINES
7
8  //  EXAMPLE  :  6.18
9
10  clear ;  clc ;  close ;  //  Clear  the  work  space  and
        console
11
12
13  //  GIVEN  DATA
14
15
16  v  =  1100;                      //  Operating  voltage
        of  the  Synchronous  Motor  in  Volts
17  p  =  4;                         //  Total  number  of
        Poles
18  m  =  3;                         //  number  of  phase
```

```scilab
19  xs = 5.0;                            // Synchrouons
        reactances in Ohms
20  f = 50;                              // Frequency in Hertz
21  delta = 9;                           // Power angle in
        degree
22  p_hp = 150;                          // Motor delivering
        power in HP
23  eta = 89/100;                        // Efficiency of
        motor
24
25
26  // CALCULATIONS
27
28  V = v/sqrt(3);                                    //
        Phase voltage in Volts
29  ws = (4*%pi*f)/p;                                 //
        Synchronous speed in Radians per second
30  // We have (746*150)/0.89) = 125730.34 W = sqrt(3)
        *1100*I*cos(theta) refer page no. 440, thus we
        get I*cos(theta) = 12530.34/(1100*sqrt(3)) =
        65.99 and E*sin(delta) = I*xs*cos(theta)
31  E = (xs*65.99)/sind(delta);                       //
        Exitation EMF per phase in Volts
32  // since E*cos(delta) > V, therefore the machine is
        over excited and power factor is leading, thus we
         get V = E*cos(delta) + I*xs*sin(theta), I*sin(
        theta) = (635.1-2109.2*cos(9)/5 = -289.586 and we
         have I*cos(theta) = 65.99 thus by solving these
        two equations we get theta = atand
        (-286.586/65.99) = 77.16 degre
33  theta = 77.16;                                    //
        Power factor angle in degree
34  I = 65.99/cosd(theta);                            //
        Current in Amphere
35  pf = cosd(theta);                                 //
        Power factor leading
36  P = (3*V*E*sind(delta))/(xs*1000);                //
        Power in kilo-Watts
```

```
37  T = (P*1000)/ws;                                      //
        torque in Newton−meter
38
39
40  // DISPLAY RESULTS
41
42  disp("EXAMPLE : 6.18: SOLUTION :−");
43  printf("\n (a) Excitation EMF, E = %.1f V \n",E)
44  printf("\n (b) Line current, I = %.2f A \n",I)
45  printf("\n (c) Power factor = %.3f leading \n",pf)
46  printf("\n (d) Power , P = %.4f kW \n",P)
47  printf("\n (e) Torque , T = %.2f N−m \n",T)
48  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
49  printf("\n         WRONGLY PRINTED ANSWERS ARE :− \n (a
        ) Power , P = 13.0667 kW instaed of %.4f kW \n",P
        )
50  printf("\n (b) Torque , T = 83.22 N−m instaed of %.2
        f N−m \n",T)
51  printf("\n From Calculation of the Power(P), rest
        all the Calculated values in the TEXT BOOK is
        WRONG because of the Power(P) value is WRONGLY
        calculated and the same used for the further
        Calculation part \n")
```

Scilab code Exa 6.19 To find efficiency induced voltage torque angle power torque

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6  // CHAPTER : 6 : SYNCHRONOUS MACHINES
```

```scilab
 7
 8  // EXAMPLE : 6.19
 9
10  clear ; clc ; close ; // Clear the work space and
        console
11
12
13  // GIVEN DATA
14
15  v = 440;                              // Operating voltage
        of the Synchronous Motor in Volts
16  p = 6;                                // Total number of
        Poles
17  m = 3;                                // Number of phase
18  xs = 5;                               // Synchrouons
        reactances per phase in Ohms
19  f = 50;                               // Frequency in Hertz
20  p_hp = 10;                            // Motor delivering
        power in HP
21  loss = 1000;                          // Total iron ,copper
        and friction losses in Watts
22  pf = 0.8;                             // Power factor
        lagging
23  I = 10;                               // Motor drawing
        current in Amphere at 0.8 PF lagging
24
25
26  // CALCULATIONS
27
28  V = v/sqrt(3);                                        //
        Phase voltage in Volts
29  ws = (4*%pi*f)/p;                                     //
        Synchronous speed in Radians per second
30  theta = acosd(pf);                                    //
        Power factor angle in degree
31  Po = p_hp*746;                                        //
        Output power in Watts
32  Pi = Po+loss;                                         //
```

```
      Input power in Watts
33 eta = (Po/Pi)*100;                                       //
      Efficiency
34 // we have V = E*cos(delta) − I*xs*sin(theta), 254 =
      E*cos(delta) − 5*10*0.6, so E*cos(delta) = 254 +
      30 = 284 and E*sin(delta) = I*xs*cos(theta) =
      5*10*0.8 = 40 by solving these two equations we
      get delta = atand(40/284) = 8.01 degree
35 delta = 8.01;                                            //
      Power angle in degree
36 E = 40/sind(delta);                                      //
      Induced EMF per phase in Volts
37 P = (3*V*E*sind(delta))/(xs*1000);                       //
      Power in Kilo−watts
38 T = (P*1000)/ws;                                         //
      Torque in Newton−meter
39
40
41 // DISPLAY RESULTS
42
43 disp("EXAMPLE : 6.19: SOLUTION :−");
44 printf("\n (a) Efficiency , eta = %.2f Percent \n",
      eta)
45 printf("\n (b) Induced EMF, E = %.f V per phase and
      \n\n      Power (Torque) angle = %.2f degree \n",E
      ,delta)
46 printf("\n (c) Power , P = %.4f kW \n",P)
47 printf("\n (d) Torque , T = %.2f N−m \n",T)
```

Scilab code Exa 6.20 To find induced voltage power and torque in each cases

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
```

```
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6  // CHAPTER : 6 : SYNCHRONOUS MACHINES
7
8  // EXAMPLE : 6.20
9
10 clear ; clc ; close ; // Clear the work space and
      console
11
12
13 // GIVEN DATA
14
15
16 v = 11*10^3;                        // Operating voltage
      of the Synchronous Motor in Volts
17 p = 4;                             // Total number of
      Poles
18 m = 3;                            // number of phase
19 xs = 7;                           // Synchrouons
      reactances per phase in Ohms
20 f = 50;                           // Frequency in Hertz
21 KVA = 1500;                       // KVA rating (whole)
22 kva = 500;                        // Each case KVA
      rating
23
24
25 // CALCULATIONS
26
27 V = v/sqrt(3);                                    //
      Phase voltage in Volts
28 ws = (4*%pi*f)/p;                                //
      Synchronous speed in Radians per second
29 I = (sqrt(3)*kva)/v;                             //
      Phase Current in Amphere
30
31 // For Case (a) 0.8 pf lagging
32
33 pf_a = 0.8;                                      //
```

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```
        Power  factor  lagging
34  pfa_a = acosd(pf_a);                            //
        Power  factor  angle  in  degree
35  // we have E*cos(delta) = V - I*xs*sin(theta) =
        6351-78.73*7*0.6 = 6020.334  and  E*sin(delta) = I*
        xs*cos(theta) = 78.73*7*0.8 = 440.888  thus  we  get
         by  sloving  these  two  equatins  E = 6036.46  V  and
        delta = atand(440.888/6020.334) = 4.19  degree
36  E_a = 6036.46;                                   //
        Induced  Voltage  in  Volts
37  delta_a = 4.19;                                  //
        Power  angle  in  degree
38  P_a = (3*V*E_a*sind(delta_a))/(xs*10^6);        //
        Power  in  Mega-Watts
39  T_a = (P_a*10^6)/ws;                            //
        Torque  in  Newton-meter
40
41  // For  Case  (b)  0.8  pf  leading
42
43  pf_b = 0.8;                                      //
        Power  factor  lagging
44  pfa_b = acosd(pf_b);                             //
        Power  factor  angle  in  degree
45  // we have E*cos(delta) = V + I*xs*sin(theta) =
        6351+78.73*7*0.6 = 6681.666  and  E*sin(delta) = I*
        xs*cos(theta) = 78.73*7*0.8 = 440.888  thus  we  get
         by  sloving  these  two  equatins  E = 6696.2  V  and
        delta = atand(440.888/6681.666) = 3.78  degree
46  E_b = 6696.2;                                    //
        Induced  Voltage  in  Volts
47  delta_b = 3.78;                                  //
        Power  angle  in  degree
48  P_b = (3*V*E_b*sind(delta_b))/(xs*10^6);        //
        Power  in  Mega-Watts
49  T_b = (P_b*10^6)/ws;                            //
        Torque  in  Newton-meter
50
51  // For  Case  (c)  UPf
```

```
52
53  pf_c = 1.0;                                          //
        Power factor lagging
54  pfa_c = acosd(pf_c);                                 //
        Power factor angle in degree
55  // we have E*cos(delta) = V = 6351 and E*sin(delta)
        = I*xs = 78.73*7 = 551.11 thus we get by sloving
        these two equatins E = 6374.9 V and delta = atand
        (551.11/6351) = 4.96 degree
56  E_c = 6374.9;                                        //
        Induced Voltage in Volts
57  delta_c = 4.96;                                      //
        Power angle in degree
58  P_c = (3*V*E_c*sind(delta_c))/(xs*10^6);             //
        Power in Mega-Watts
59  T_c = (P_c*10^6)/ws;                                 //
        Torque in Newton-meter
60
61
62  // DISPLAY RESULTS
63
64  disp("EXAMPLE : 6.20: SOLUTION :-");
65  printf("\n For Case (a) 0.80 pf lagging :- \n (a)
        Induced EMF, E = %.2f V \n",E_a)
66  printf("\n (b) Power , P = %.1f MW \n",P_a)
67  printf("\n (c) Torque , T = %.2f N-m \n",T_a)
68  printf("\n For Case (b) 0.80 pf leading :- \n (a)
        Induced EMF, E = %.1f V \n",E_b)
69  printf("\n (b) Power , P = %.3f MW \n",P_b)
70  printf("\n (c) Torque , T = %.2f N-m \n",T_b)
71  printf("\n For Case (a) UPf :- \n (a) Induced EMF, E
        = %.1f V \n",E_c)
72  printf("\n (b) Power , P = %.2f MW \n",P_c)
73  printf("\n (c) Torque , T = %.f N-m \n",T_c)
```

Scilab code Exa 6.21 To find induced EMF torque angle power torque current and pf

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.21
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 v = 440;                          // Operating voltage
      of the Synchronous Motor in Volts
17 f = 50;                           // Operating
      Frequency of the Synchronous Motor in Hertz
18 xd = 10;                          // Direct axis
      reactances in Ohms
19 xq = 7.0;                         // Quadrature axis
      reactances in Ohms
20 p = 6;                            // Total number of
      Poles
21 pf = 0.8;                         // Power factor
      lagging
22 i = 10;                           // Motor drawing
      current in Amphere
23
24
25 // CALCULATIONS
26
27 V = v/sqrt(3);                                    //
```

```scilab
      Phase  voltage  in  Volts
28  ws  =  (4*%pi*f)/p;                                        //
      Synchronous  speed  in  Radians  per  second
29  theta  =  acosd ( pf ) ;                                   //
      Power  factor  angle  in  degree
30  I  =  10*( cosd ( theta )+(%i * sind ( theta ) ) ) ;        //
      Motor  drawing  current  in  Amphere  at  0.8  PF
      leading
31  delta  =  atand (( i * xq * cosd ( theta ) ) /( V+i * xq * sind ( theta )
      ) ) ;                   //  Power  angle  for  motoring  mode
      in  degree
32  Iq  =  i * cosd ( theta + delta ) ;
                                                              //
      Current  in  Amphere
33  Id  =  i * sind ( theta + delta ) ;
                                                              //
      Current  in  Amphere
34  Eo  =  V* cosd ( delta )  +  Id * xd ;
                                                              //
      Induced  EMF  in  Volts
35  P  =  (( 3* V* Eo * sind ( delta ) ) / xd )+(3* V^2*((1/ xq ) -(1/ xd ) )
      * sind (2* delta ) ) /2;                        //  Power
      in  Watts
36  T  =  (( 3* V* Eo * sind ( delta ) ) /( xd * ws ))+(3* V^2*((1/ xq )
      -(1/ xd ) ) * sind (2* delta ) ) /(2* ws ) ;            //
      Torque  in  Newton−meter
37
38  //  when  the  machine  is  running  as  alternator ,  the
      magnitude  of  induced  EMF  =  323.38V.  Let  the  new
      current  will  be  Inew  at  lagging  power  factor
      thetanew . Now  torque  angle  is  10.71  deg  from
      phasor  diagram  Figure  6.51  and  page  no.  444  we
      get  V+Id * xd * cos ( delta )−Iq * xq * sin ( delta )  =  Eo * cos (
      delta ) ,  254+9.825* Id −1.3 Iq  =  317.75,  9.825* Id
      −1.3* Iq  =  63.75,  7.56* Id−Iq  =  49  and  we  have  Id *
      xd * sin ( delta )+Iq * xq * cosdelta )  =  Eo * sin ( delta ) ,
      1.85* Id +6.88* Iq  =  60.1,  0.27* Id+Iq  =  8.74  by
      solving  these  two  equations  we  get  Idnew  =
```

$123.85/10.095 = 12.27A$ and Iqnew = 5.43A

```
39  Iqnew = 5.43;                                      //
       New current in Amphere
40  Idnew = 12.27;                                     //
       New current in Amphere
41  Inew = sqrt(Idnew^2 + Iqnew^2);                    //
       New total Current in Amphere
42  // We know that torque angle, tan(delta) = (I*xd*cos
       (theta))/(V+I*Xq*sin(theta)) so by calutaion for
       new power factor angle thetanew we get, tan
       (10.17) = (13.42*7*cos(thetanew))/(254+13.42*7*
       sin(thetanew)), 0.189(254+13.42*7*sin(thetanew) =
        13.42*7*cos(thetanew), 48-93.94cos(thetanew)
       +17.75*sin(thetanew) = 0 by solving this equatuon
        we gwt thetanew = 49.5 lagging
43  thetanew = 49.5;
       // New power factor angle in degree
44  pfnew = cosd(thetanew);
       // Power factor lagging
45
46
47  // DISPLAY RESULTS
48
49  disp("EXAMPLE : 6.21: SOLUTION :-");
50  printf("\n (a) Induced EMF, E = %.2f V \n",Eo)
51  printf("\n (b) Power (Torque) angle = %.2f degree \n
       ",delta)
52  printf("\n      Power , P = %.2f W \n",P)
53  printf("\n      Torque , T = %.2f N-m \n",T)
54  printf("\n (c) when the machine is running as
       alternator requirements are:- \n\n       New
       Current = %.2f A\n",Inew)
55  printf("\n      Power factor = %.3f lagging \n",pfnew
       )
```

Scilab code Exa 6.22 To find terminal voltages load currents active power output and no load circulating current

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6  // CHAPTER : 6 : SYNCHRONOUS MACHINES
7
8  // EXAMPLE : 6.22
9
10 clear ; clc ; close ; // Clear the work space and
       console
11
12
13 // GIVEN DATA
14
15 E1 = 1100 + (%i*0);                        // EMFs
       of two identicel synchronous Generators in Volts
       per phase
16 E2 = 1100*(cosd(5)-(%i*sind(5)));          // EMF
       in Volts per phase
17 Zl = 1.0 + (%i*1.0);                       // Load
       impedance in Ohms per phase
18 Zs1 = 0.15 + (%i*2.1);                     //
       Synchronous impedance in Ohms per phase
19 Zs2 = 0.2 + (%i*3.3);                      //
       Synchronous impedance in Ohms per phase
20 f = 50;                                    //
       Frequency in Hertz
21
22
23 // CALCULATONS
24
25 Ys1 = 1/Zs1;
       // Synchronous Admittance in Ohms per phase
26 Ys2 = 1/Zs2;
```

```
          // Synchronous Admittance in Ohms per ohase
27  Yl = 1/Zl;
          // Load Admittance in Ohms per ohase
28  V = ((E1*Ys1)+(E2*Ys2))/(Yl+Ys2+Ys1);
          // Terminal Voltage in Volts per phase (From
          Millman's Theorem)
29  I1 = (E1-V)/Zs1;
          // Individual current in Amphere per phase
30  I2 = (E2-V)/Zs2;
          // Individual current in Amphere per phase
31  P1 = abs(V)*abs(I1)*cosd(atand(imag(V),real(V))-
          atand(imag(I1),real(I1)));
                                          // Per phase
          actice power in Watts
32  P2 = abs(V)*abs(I2)*cosd(atand(imag(V),real(V))-
          atand(imag(I2),real(I2)));
                                          // Per phase
          actice power in Watts
33  Ic = (E2-E1)/(Zs1+Zs2);
          // No-load circulating current in Amphere per
          phase
34
35
36  // DISPLAY RESULTS
37
38  disp("EXAMPLE : 6.22 : SOLUTION :-");
39  printf("\n (a) Terminal Voltage per phase, V = %.2f
          < %.1f V \n",abs(V),atand(imag(V),real(V)))
40  printf("\n (b) Individual currents per phase, I1 = %
          .f < %.1f A \n\n         I2 = %.1f < %.1f A \n",abs(
          I1),atand(imag(I1),real(I1)),abs(I2),atand(imag(
          I2),real(I2)))
41  printf("\n (c) Per phase Active Power , P1 = %.f W \
          n\n         P2 = %.1f W \n ",P1,P2)
42  printf("\n (d) No-load current per phase, Ic = %.2f
          < %.2f A \n",abs(Ic),atand(imag(Ic),real(Ic)))
```
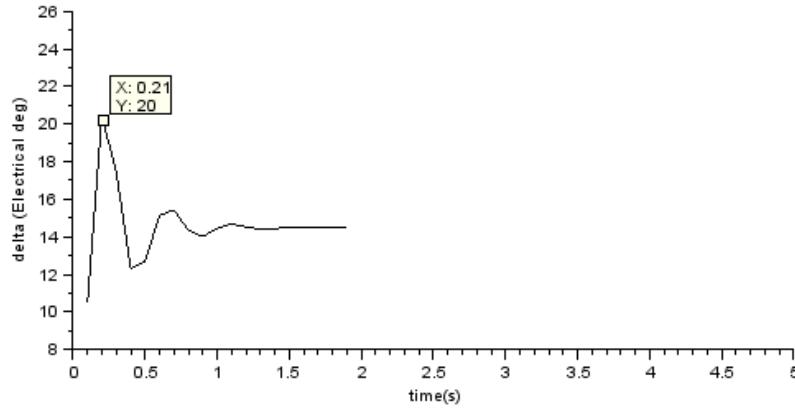
Figure 6.1: To find maximum value of power angle and maximum value of overshoot

Scilab code Exa 6.23 To find maximum value of power angle and maximum value of overshoot

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6  // CHAPTER : 6 : SYNCHRONOUS MACHINES
7
8  // EXAMPLE : 6.23
9
10 clear ; clc ; close ; // Clear the work space and
      console
11
12
13 // GIVEN DATA
```

```scilab
14
15  p = 4;                               // Number  of  the
        poles  in  the  Alternator
16  f = 50;                              // Frequency  in
        Hertz
17  pkw = 500;                           // Alternator
        delivering  load  in  kilo−watts
18  pkwinc = 1000;                       // Generator
        increases  its  share  of  the  common  elictrical  in
        kilo−watts
19  Kj = 1.5;                            // Inertia
        acceleration  coefficient  for  the  combined  prime
        mover−alternator  in  N−m/elec  deg/second  square
20  Kd = 12;                             // Damping  torque
        coefficient  in  N−m/elec  deg/second
21  delta1 = 9;                          // Initial  value  of
        the  Power  angle  in  degree
22
23
24  // CALCULATIONS
25
26  delta2 = (pkwinc/pkw)*delta1;
                                         // Final  value (
        maximum  value)  of  the  Power  angle  in  degree (
        considering  Linear  variation)
27  ws = (4*%pi*f)/p;
                                                           //
        Rotational  speed  in  Radians  per  second
28  Ts = (pkw*1000)/ws;
                                                           //
        Synchornizing  torque  at  500kW  in  N−m
29  Ks = Ts/delta1;
                                                           //
        Synchornizing  torque  cofficient  at  500kW  in  N−m/
        elec−deg
30  // Laplace  transform  of  the  swing  Equation  can  be
        written  as  :−  s^2 + ((Kd/Kj)*s) + (Ks/Kj) = 0, s
        ^2 + (12/1.5)s + (353.86/1.5) = 0  and  compring
```

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```scilab
      with the standard equation s^2 + s(2*zeta*Wn) +
      Wn^2 = 0 we get:- mentined below  (refer page no.
       454 and 455)
31 Wn = sqrt(Ks/Kj);
                                               //
      Natural frequency of oscillations in Radians per
      second
32 fn = Wn/(2*%pi);
                                               //
      Frequency of natural oscillations in Hertz
33 zeta = (1*Kd)/(2*Wn*Kj);
                                        // Damping
      ratio
34 Wd = Wn*(sqrt(1-zeta^2));
                                      // Frequency of
       damped oscillations in radians/s
35 fd = Wd/(2*%pi);
                                               //
      Frequency of damped oscillations in Hertz
36 ts = 5/(zeta*Wn);
                                               //
      Settling time in second
37 deltamax = delta1 + 1.42*(delta2-delta1);
                         // The maximum overshoot for
      damping ratio of 0.2604 is about 42% the maximum
      appoximate value of the overshoot in terms of 1%
      tolearance band in Electrical degree
38
39
40 // DISPLAY RESULTS
41
42 disp("EXAMPLE : 6.23: SOLUTION :-");
43 printf("\n (a.1) Final value (maximum value) of the
      Power angle (considering Linear variation),
      delta2 = %.f degree \n",delta2)
44 printf("\n (a.2) Natural frequency of oscillations,
      Ns = %.2f radians/s \n",Wn)
45 printf("\n (a.3) Damping ratio, zeta = %.4f \n",zeta
```

```
      )
46 printf(”\n  (a.4)  Frequency  of  damped  oscillations ,
      Wd = %.2f  radians/s  \n”,Wd)
47 printf(”\n  (a.5)  Settling  time ,  ts  = %.2f  seconds  \n
      ”,ts)
48 printf(”\n   (b)   The  maximum  overshoot  for  damping
      ratio  of  0.2604  is  about  42  percent  the  maximum
      appoximate  value  of  the  overshoot  in  terms  of  1
      percent  tolearance  band  is ,  deltamax  = %.2f
      degree  \n”,deltamax)
49 printf(”\n\n FOR CASE  (C)  CANNOT  BE  DO  IT  IN  THIS
      BECAUSE  AS  IT  REQUIRES  MATLAB  SIMULINK  \n”)
```

This code can be downloaded from the website wwww.scilab.in

Scilab code Exa 6.25 To find reactive kVA of the motor and overall pf of the motor and load and resultant current

```
1
2 // ELECTRICAL  MACHINES
3 // R.K. Srivastava
4 //  First  Impression  2011
5 // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7 // CHAPTER  :  6  :  SYNCHRONOUS  MACHINES
8
9 // EXAMPLE  :  6.25
10
11 clear ; clc ; close ; // Clear  the  work  space  and
      console
12
13
14 // GIVEN  DATA
15
```

```
16  v = 440;                              // Operating voltage
       of the Synchronous generator in Volts
17  f = 50;                               // Operating
       Frequency of the Synchronous generator in Hertz
18  m = 3;                                // Total number of
       Phase
19  pf = 0.8;                             // Power factor
       lagging
20  Il = 100;                             // Motor drawing
       current in Amphere
21  xs = 2;                               // Synchronous
       reactances in Ohms
22  delta = 20;                           // Power angle in
       degree
23  P = 50*10^3;                          // Total Power
       developed by the motor in Watts
24  Ppp = (50*10^3)/3;                    // Power developed by
       the motor per phase in Watts
25
26
27  // CALCULATIONS
28
29  V = v/sqrt(3);                                          //
       Phase voltage in Volts
30  Eo = (Ppp*xs)/(3*V*sind(delta));                       //
       Per phase Induced voltage in Volts
31  // Let us assume thetam is Power factor angle in
       degree and Im is the Motor current now, from
       phasor diagram figure 6.67 page no. 465 we get,
       Eo*cosd(delta) = V+Im*xs*sind(thetam), Im*sind(
       thetam) = ((383.84*cosd(20))-254.03)/2 = 53.35
       and Im*xs*cosd(thetam) = Eo*sin(delta), Im*cosd(
       theta) = ((383.84*sind(20))/2 = 65.60 by sloving
       these two equations we get Im = sqrt(65.60^2 +
       53.35^2) = 84.56 A and thetam = atand
       (53.35/65.60) = 39.13 degree
32  Im = sqrt(65.60^2 + 53.35^2);
                                    // Motor current in
```

```
      Amphere
33  thetam = atand (53.35/65.60) ;
                                    // Power factor angle
       in degree
34  kVA = ( sqrt (3) *V*Im*sind ( thetam ) ) /1000;
                          // Rective kVA of the motor in
      kVAR
35  thetal = acosd ( pf ) ;
                                         // Load power
        factor angle in degree
36  thetaR = atand (( Im*sind ( thetam ) - Il*sind ( thetal ) ) /( Im
      *cosd ( thetam ) +Il*cosd ( thetal ) ) ) ;
                                                     //
      Resultant Power factor angle in degree
37  ovpf = cosd ( thetaR ) ;
                                         // Overall
      Power factor lagging
38  IR = sqrt (( Im*sind ( thetam ) - Il*sind ( thetal ) ) ^2 + ( Im*
      cosd ( thetam ) +Il*cosd ( thetal ) ) ^2) ;
                                                     //
      Resultant ( magnitude ) current in Amphere refer
      phasor diagram figure 6.69 page no. 467
39
40
41  // DISPLAY RESULTS
42
43  disp (" EXAMPLE : 6.25: SOLUTION :−") ;
44  printf ("\n (a) Rective kVA of the motor = %.3 f kVAR
      \n", kVA )
45  printf ("\n (b) Overall Power factor of the load and
       motor = %.4 f lagging and \n", ovpf )
46  printf ("\n     Resultant ( magnitude ) current = %.2 f
      A \n", IR )
```

Scilab code Exa 6.27 To find Overall and individual currents of the machines and pf

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6  // CHAPTER : 6 : SYNCHRONOUS MACHINES
7
8  // EXAMPLE : 6.27
9
10 clear ; clc ; close ; // Clear the work space and
      console
11
12
13 // GIVEN DATA
14
15 v = 440;                        // Operating voltage
      of the Synchronous generator in Volts
16 f = 50;                         // Operating
      Frequency of the Synchronous generator in Hertz
17 m = 3;                          // Total number of
      Phase
18 xs = 5;                         // Synchronous
      reactances in Ohms
19 Eo = 500;                       // Indduced Voltage
      in Volts per phase
20 R1 = 0.1;                       // Circuit Parameter
      in Ohms
21 R2 = 0.1;                       // Circuit Parameter
      in Ohms
22 X1 = 1.55;                      // Circuit Parameter
      in Ohms
23 X2 = 1.55;                      // Circuit Parameter
      in Ohms
24 s = 0.03;                       // Slip
25 P = 30*10^3;                    // Total Power
```

```
        developed  by  the  motor  in  Watts
26
27
28  // CALCULATIONS
29
30  V = v/sqrt(3);                                    //
        Phase  voltage  in  Volts
31  Ii = V/sqrt((R1+R2/s)^2 + (X1+X2)^2);            //
        Per  phase  induction  motor  current  in  Amphere
32  thetal = atand((X1+X2)/(R1+R2/s));              //
        Power  factor  angle  of  the  induction  motor  in
        degree
33  pf = cosd(thetal);                                //
        Power  factor  of  the  induction  motor  lagging
34  // Let  us  assume  thetam  is  leading  Power  factor
        angle  in  degree  and  Im  is  the  synchronous  Motor
        current  now,  from  phasor  diagram  figure  6.70  page
        no.  469
35  delta = asind((xs*P)/(3*V*Eo));                  //
        Power  angle  in  degree
36  // From  phasor  diagram  figure  6.70  page  no.  469  we
        have,  Im*xs*cos(thetam) = Eo*sin(delta),  Im*cos(
        delta) = ((500*sind(23.18))/5 = 39.37  and  Eo*cosd
        (delta) = V+Im*xs*sind(thetam),  Im*sind(thetam) =
        ((500*cosd(23.18))-254.03)/5 = 41.12  by  sloving
        these  two  equations  we  get  Im = sqrt(39.37^2 +
        41.12^2) = 56.93  A  and  thetam = atand
        (41.12/39.37) = 46.25  degree
37  Im = sqrt(39.37^2 + 41.12^2);
                                  // Motor  current  in
        Amphere
38  thetam = atand(41.12/39.37);
                                  // Power  factor  angle
        in  degree
39  kVA = (sqrt(3)*V*Im*sind(thetam))/1000;
                        // Rective  kVA  of  the  motor  in
        kVAR
40  II = Ii * exp( %i * (-thetal) * %pi/180);
```

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```
                          // Induction Motor current in
      Amphere
41  Im = Im * exp( %i * thetam * %pi/180);
                          // Synchronous Motor current in
      Amphere
42  It = II + Im;
                                                      //
      Total per phase current in Amphere
43  ovpf = cosd(atand(imag(It),real(It)));
                          // Overall Power factor leading
44
45
46  // DISPLAY RESULTS
47
48  disp("EXAMPLE : 6.27: SOLUTION :−");
49  printf("\n (a) Reactive kVA of the motor = %.3 f kVAR
      \n",kVA)
50  printf("\n (b) Individual currents:− \n
      Induction Motor current , II = %.2 f + i(%.2 f) A \n
      \n      Synchronous Motor current , Im = %.2 f + i(%
      .2 f) A \n",real(II),imag(II),real(Im),imag(Im))
51  printf("\n (c) Resultant (overall) current = %.2 f <
      %.2 f A \n",abs(It),atand(imag(It),real(It)))
52  printf("\n (d) Overall Power factor = %.4 f leading \
      n",ovpf)
```

Scilab code Exa 6.28 To find torque and operating speed

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
```

```scilab
 8
 9  // EXAMPLE : 6.28
10
11  clear ; clc ; close ; // Clear  the  work  space  and
        console
12
13
14  // GIVEN DATA
15
16
17  V = 400;                              // Operating  voltage
        of  the  Synchronous  generator  in  Volts
18  f = 50;                               // Operating
        Frequency  of  the  Synchronous  generator  in  Hertz
19  xd = 12;                              // Direct  axis
        reactances  in  Ohms
20  xq = 5;                               // Quadrature  axis
        reactances  in  Ohms
21  delta = 15;                           // Power(Torque)  angle
         in  degree
22  p = 2;                                // Number  of  the  poles
23  m = 3;                                // Number  of  the  phase
24
25
26  // CALCULATIONS
27
28  v = V/sqrt(3);
                                              // Rated
        Phase  Votage  in  Volts
29  Ns = (120*f)/p;
                                              //
        Operating  speed  in  RPM
30  Ws = (2*%pi*f)/(p/2);
                                              // Synchronous
        speed  in  radians/s
31  T = (3*v^2*sind(2*delta)/(2*Ws))*((1/xq)-(1/xd));
            // Developed  Torque  in  Newton-meter
32
```

```
33
34 // DISPLAY RESULTS
35
36 disp("EXAMPLE : 6.28: SOLUTION :-");
37 printf("\n (a) Operating speed , Ns = %.f RPM \n",Ns)
38 printf("\n (b) Developed Torque , T = %.2f N-m \n",T
       )
```

Scilab code Exa 6.29 To find torque and operating speed

```
1
2 // ELECTRICAL MACHINES
3 // R.K.Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9 // EXAMPLE : 6.29
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 f = 400;                              // Operating
      Frequency of the Synchronous generator in Hertz
17 Ld = 50*10^-3;                        // Direct axis
      reactances in Henry
18 Lq = 15*10^-3;                        // Quadrature
      axis reactances in Henry
19 delta = 15;                          // Power(Torque
      ) angle in degree
20 p = 2;                               // Number of
```

```
         the  poles
21  m = 3;                                           // Number  of
         the  phase
22  I = 10;                                          // Operating
         current  in  Amphere
23
24
25  // CALCULATIONS
26
27  Ns = (120*f)/p;
                                                         //
         Operating  speed  in  RPM
28  Ws = (2*%pi*f)/(p/2);
                                                     //
         Synchronous  speed  in  radians/s
29  xd = 2*%pi*f*Ld;
                                                         //
         Direct  axis  reactances  in  reactance
30  xq = 2*%pi*f*Lq;
                                                         //
         Quadrature  axis  reactances  in  reactance
31  E1 = 0;

         // Induced  EMF  in  Volts  (Its  ZERO  beacuse  when
         field  winding  current  is  zero)
32  v = xq*I;

         // Applied  voltage  in  Volts
33  T = (3*v^2*sind(2*delta)/(2*Ws))*((1/xq)-(1/xd));
                         // Developed  Torque  in  Newton-meter
34
35
36  // DISPLAY RESULTS
37
38  disp("EXAMPLE :  6.29: SOLUTION :-");
39  printf("\n (a)  Operating  speed ,  Ns = %.f RPM \n",Ns)
40  printf("\n (b)  Developed  Torque ,  T = %.5f N-m \n",T
         )
```

```
41  printf(”\n\n      [ TEXT BOOK  SOLUTION  IS  PRINTED
        WRONGLY  (  I  verified  by  manual  calculation  )]\n”
        );
42  printf(”\n          WRONGLY  PRINTED  ANSWERS  ARE  :−  (a)
        xd  =  12.56  instead  of  %.2 f  Ohms  \n ”,xd);
43  printf(”\n                                          (b)
        xq  =  3.768  instead  of  %.2 f  Ohms  \n ”,xq);
44  printf(”\n                                          (c)  v
        =  36.68  instead  of  %.2 f  V  \n ”,v);
45  printf(”\n                                          (d)  T
        =  0.07875  instead  of  %.4 f  N–m  \n ”,T);
46  printf(”\n From  Calculation  of  the  d−axis  and  q−axis
        reactance  (xd  and  xq  respectively),  rest  all  the
        Calculated  values  in  the  TEXT BOOK  is  WRONG
        because  of  the  d−axis  and  q−axis  reactance  (xd
        and  xq  respectively)  value  is  WRONGLY  calculated
        and  the  same  used  for  the  further  Calculation
        part  \n”)
```

Scilab code Exa 6.30 To find power and torque

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  // First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
7  // CHAPTER  :  6  :  SYNCHRONOUS  MACHINES
8
9  // EXAMPLE  :  6.30
10
11 clear ; clc ; close ; // Clear  the  work  space  and
        console
12
13
```

```
14  // GIVEN DATA
15
16  f = 50;                                // Operating  Frequency
        of  the  Synchronous  generator  in  Hertz
17  p = 2;                                 // Number  of  the  poles
18  Pt = 800;                              // Total  loss  in  Watts
19  Pr = 10;                               // Rotational  loss  in
        Watts
20
21
22  // CALCULATIONS
23
24  Ws = (4*%pi*f)/p;
                                                      //
        Synchronous  speed  in  radians/s
25  Ph = Pt-Pr;
                                                      //
        Hysteresis  loss  refered  to  stator  in  Watts
26  Th = Ph/Ws;
                                                      //
        Torque  at  the  shaft  in  Newton−meter
27
28
29  // DISPLAY RESULTS
30
31  disp("EXAMPLE :  6.30: SOLUTION :−");
32  printf("\n (a) Power  at  the  shaft ,  Ph = %.f W \n",Ph
        )
33  printf("\n )b) Torque  at  the  shaft  ,  Th = %.2f N−m \
        n",Th)
```

Scilab code Exa 6.31 To find induced EMF per phase torque angle and power in each cases

1

```scilab
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6  // CHAPTER : 6 : SYNCHRONOUS MACHINES
7
8  // EXAMPLE : 6.31
9
10 clear ; clc ; close ; // Clear the work space and
      console
11
12
13 // GIVEN DATA
14
15 Pi = 2*10^6;                              // Power
       input in Volt-Amphere
16 v = 6.6*10^3;                            //
      Operating voltage in Volts
17
18
19 // CALCULATIONS
20
21 I = Pi/(v*sqrt(3));                      // Rated
       current in Amphere
22 V = v/sqrt(3);                           // Phase
       voltage in Volts
23 xs = v/(I*sqrt(3));                      //
      Synchronous reactance in Ohms
24
25 // For case (a) 0.8 pf lagging
26
27 pf_a = 0.8;                              // Power
       factor
28 pfa_a = acosd(pf_a);                     // Power
       factor angle in degree
29 a_a = (V + (I*xs*sind(pfa_a)));
30 b_a = (I*xs*cosd(pfa_a));
31 E_a = sqrt(a_a^2 + b_a^2);               //
```

```scilab
        Induced EMF in Volts
32  delta_a = atand(b_a/a_a);                      //
        Torque (power) angle in degree
33  P_a = (3*V*E_a*sind(delta_a))/(xs*10^6);    // Power
        developed in MVA
34
35  // For case (b) 0.8 pf leading
36
37  pf_b = 0.8;                                    // Power
        factor
38  pfa_b = acosd(pf_b);                           // Power
        factor angle in degree
39  a_b = (V - (I*xs*sind(pfa_a)));
40  b_b = (I*xs*cosd(pfa_b));
41  E_b = sqrt(a_b^2 + b_b^2);                     //
        Induced EMF in Volts
42  delta_b = atand(b_b/a_b);                      //
        Torque (power) angle in degree
43  P_b = (3*V*E_b*sind(delta_b))/(xs*10^6);    // Power
        developed in MVA
44
45  // For case (c) UPF
46
47  pf_c = 1.0;                                    // Power
        factor
48  pfa_c = acosd(pf_c);                           // Power
        factor angle in degree
49  a_c = V;
50  b_c = I*xs;
51  E_c = sqrt(a_c^2 + b_c^2);                     //
        Induced EMF in Volts
52  delta_c = atand(b_c/a_c);                      //
        Torque (power) angle in degree
53  P_c = (3*V*E_c*sind(delta_c))/(xs*10^6);    // Power
        developed in MVA
54
55
56  disp("EXAMPLE : 6.31: SOLUTION :-");
```

```
57  printf("\n For Case (a) 0.80 lagging Power factor \n
        Induced EMF, EMF = %.2 f V \n",E_a)
58  printf("\n Power (Torque) angle = %.2 f degree \n",
        delta_a)
59  printf("\n Power developed, P = %.1 f MVA \n",P_a)
60  printf("\n For Case (b) 0.80 leading Power factor \n
        Induced EMF, EMF = %. f V \n",E_b)
61  printf("\n Power (Torque) angle = %.2 f degree \n",
        delta_b)
62  printf("\n Power developed, P = %.3 f MVA \n",P_b)
63  printf("\n For Case (c) Unity Power Factor \n
        Induced EMF, EMF = %.1 f V \n",E_c)
64  printf("\n Power (Torque) angle = %.2 f degree \n",
        delta_c)
65  printf("\n Power developed, P = %.1 f MVA \n",P_c)
66  printf("\n\n     [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
67  printf("\n       WRONGLY PRINTED ANSWERS ARE :−   xs =
        20.14 instead of %.2 f Ohms \n ",xs);
68  printf("\n  For Case (a) 0.80 lagging Pf (a.1)  E =
        6561.42 instead of %.2 f V \n ",E_a);
69  printf("\n                              (a.2)
        delta = 25.45 instead of %.2 f degree \n ",delta_a
        );
70  printf("\n  For Case (b) 0.80 leading Pf (b.1)  E =
        3290 instead of %.1 f V \n ",E_b);
71  printf("\n                              (b.2)
        delta = 58.98 instead of %.2 f degree \n ",delta_b
        );
72  printf("\n                              (b.3)
        Power developed = 1.617 instead of %.3 f MVA \n ",
        P_b);
73  printf("\n  For Case (c) UPF  (c.1)  E = 5190.2
        instead of %.2 f V \n ",E_c);
74  printf("\n                        (c.2)  delta = 42.77
        instead of %.2 f degree \n ",delta_c);
75  printf("\n In all the three cases from Calculation
```

of the Synchronous reactance (xs), rest all the
Calculated values in the TEXT BOOK is WRONG
because of the Synchronous reactance (xs) value
is WRONGLY calculated and the same used for the
further Calculation part \n")

Scilab code Exa 6.32 To find induced EMF per phase power angle and
percent regulation

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.32
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15 // Refer phasor diagram figure 6.76 and page no. 476
16
17 pf = 0.8;
                                                    //
      Power factor lagging
18 pa = acosd(pf);
                                                // Power
      factor angle in degree
19 v = 1.0 * exp( %i * pa * %pi/180);
                          // Operating voltage of the
      alternator in pu
```

```scilab
20  xd = 0.8;
                                                                    //
      Direct axis reactances in pu
21  xq = 0.4;
                                                                    //
      Quadrature axis reactances in pu
22  I = 1.0;
                                                                    //
       Current in pu taking this as reference
23
24
25  // CALCULATIONS
26
27  A = v + (%i*xq*I);
28  delta = atand(imag(A),real(A))-pa;
                                // Power angle in degree
29  Iq = I * cosd(atand(imag(A),real(A)));
                        // d-axis currents in Amphere
30
31  Id = I * sind(atand(imag(A),real(A)));
                        // q-axis currents in Amphere
32  E = abs(v)*cosd(delta) + Id*xd;
                                // Induced EMF per phase
      in Per unit
33  pr = ((abs(E)-abs(v))/abs(v))*100;
                                // Percentage regulation
34
35  // DISPLAY RESULTS
36
37  disp("EXAMPLE : 6.32: SOLUTION :-");
38  printf("\n (a) Induced EMF per phase, E = %.4f < %.2
      f pu \n",E,delta)
39  printf("\n (b) Power angle = %.2f degree \n",delta)
40  printf("\n (C) Percenatge Regulation, R = %.2f
      Percent \n",pr)
41  printf("\n\n IN THIS PROBLEM PERCENTAGE REGULATION
      IS NOT CALCULATED IN THE TEXT BOOK\n")
```

Scilab code Exa 6.33 To find the ratio of the maximum electromagnetic torque to the actual electromagnetic torque

```scilab
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 6 : SYNCHRONOUS MACHINES
8
9  // EXAMPLE : 6.33
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 v = 6.6*10^3;                        // Operating voltage
       of the Synchronous motor in Volts
17 P = 5*10^6;                          // Operating power of
        the Synchronous motor in Watts
18 pf = 1.0;                            // Power factor
19 xd = 3.0;                            // Direct axis
       reactances in Ohms
20 xq = 1.0;                            // Quadrature axis
       reactances in Ohms
21 eta = 0.98;                          // OPerating
       efficiency
22
23
24 // CALCULATIONS
25
```

```
26  V = v/sqrt(3);                                          //
        Per phase voltage in Volts
27  I = P/(eta*v*sqrt(3));                                  //
        Line current in Amphere
28  delta = atand((xq*I)/v);                               //
        power angle in degree
29  E = v*cosd(delta) + xd*I*sind(delta);                  //
        Induced EMF in Volts
30  Tmax = ((3*E*V*sind(90))/xd) + ((3*V^2*sind(180))/2)
        *((1/xq)-(1/xd));
        // Maximum electromagnetic torque in N–m
31  T = ((3*E*V*sind(delta))/xd) + ((3*V^2*sind(2*delta)
        )/2)*((1/xq)-(1/xd));
32                                  // Actual electromagnetic
                                       torque in N–m
33  Ratio = Tmax/T;                                        //
        Ratio of the Maximum electromagnetic torque to
        the actual electromagnetic torque
34
35
36  // DISPLAY RESULTS
37
38  disp("EXAMPLE : 6.33: SOLUTION :-");
39  printf("\n (a) Ratio of the Maximum electromagnetic
        torque to the actual electromagnetic torque is %
        .2f \n",Ratio)
40  printf("\n\n    [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
41  printf("\n        WRONGLY PRINTED ANSWERS ARE :- (a)
        delta = 2.41 instead of %.2f degree \n ",delta);
42  printf("\n                                        (b) E
        = 6379 instead of %.2f V \n ",E);
43  printf("\n                                        (c)
        Ratio = 10.84 instead of %.2f \n ",Ratio);
44  printf("\n From Calculation of the Power angle (
        delta), rest all the Calculated values in the
        TEXT BOOK is WRONG because of the Power angle (
```

delta) value is WRONGLY calculated and the same used for the further Calculation part \n")

Chapter 7

Special Motors and Introduction to Generalized Machines Theory

Scilab code Exa 7.1 To find induced EMF

```
1
2 // ELECTRICAL MACHINES
3 // R.K. Srivastava
4 // First Impression 2011
5 // CENGAGE LEARNING INDIA PVT. LTD
6
7 // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
       GENERALIZED MACHINE THEORY
8
9 // EXAMPLE : 7.1
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
```

```
16  D = 35*10^-2;                              // Outer
        diameter of the conducting disk in Meter
17  d = 10*10^-2;                              // Inner
        diameter of the conducting disk in Meter
18  B = 1.0;                                   // Axial
        magnetic field in Telsa
19  N = 900;                                   //
        Rotating shaft running in RPM
20
21
22  // CALCULATIONS
23
24  Wr = (2*%pi*N)/60;                         //
        Rotational angular speed in radians/s
25  Er = ((D^2-d^2)*B*Wr)/8;                   // EMF
        induced in Volts
26
27
28  // DISPLAY RESULTS
29
30  disp("EXAMPLE : 7.1: SOLUTION :-");
31  printf("\n (a) Induced EMF in the outer and inner
        rims of the disk, Er = %.4f V \n",Er)
```

Scilab code Exa 7.2 To find torque and number of the conductors required

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
        GENERALIZED MACHINE THEORY
8
```

```
9  // EXAMPLE : 7.2
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 D = 0.120;                       // Outer Radius of the
       Printed Circuit Motor in meter
17 d = 0.060;                       // Inner Radius of the
       Printed Circuit Motor in meter
18    B = 0.7;                      // Axial Flux Density in
             Telsa
19 V = 12;                          // Volage Supplied to
       the Motor in Volts
20 R = 2700;                        // Motor Speed in RPM
21 n = 0.65;                        // Efficiency of Motor
22 p = 94;                          // Output Power of Motor
        in Watts
23 I = 12;                          // Motor current in
       Ampheres
24
25
26 // CALCULATIONS
27
28 w = ((2*(%pi))*R)/60;           // The Angular Velocity
        in Radians/second
29 T = p/w;                         // Torque in Newton−
       Meter
30 N = (8*T)/((D^2-d^2)*B*I)       // Total Number of
       Conductors
31
32
33 // DISPLAY RESULTS
34
35 disp("EXAMPLE : 7.2 : SOLUTION :−") ;
36 printf("\n (a) Torque , T = %.2f N–m \n ",T);
```

```
37  printf("\n (b) Total Number of Conductors, N = %.2f
        nearly 30 \n",N);
```

Scilab code Exa 7.3 To find resultant torque and stator phase currents

```
1
2   // ELECTRICAL MACHINES
3   // R.K.Srivastava
4   // First Impression 2011
5   // CENGAGE LEARNING INDIA PVT. LTD
6
7   // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
        GENERALIZED MACHINE THEORY
8
9   // EXAMPLE : 7.3
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  m = 2;                                              //
        Total number of phase in servo Motor
17  f = 50;                                             //
        Frequency in Hertz
18  V = 220;                                            //
        Operating Voltage of the servo Motor in Volts
19  R1 = 250;                                           //
        Circuit Parameter in Ohms
20  R2 = 750;                                           //
        Circuit Parameter in Ohms
21  X1 = 50;                                            //
        Circuit Parameter in Ohms
22  X2 = 50;                                            //
```

```
      Circuit  Parameter  in  Ohms
23  Xm  =  1000;                                        //
      Circuit  Parameter  in  Ohms
24  s  =  0.6;                                          //
      Slip
25  Va  =  220;                                         //
      Unbalanced  Voltage  in  Volts
26  Vb  =  150  *  exp(%i  *  (-60)  *  %pi/180);       //
      Unbalanced  Voltage  in  Volts
27
28
29  // CALCULATIONS
30
31  Va1  =  (Va  +  %i*Vb)/2;
                                              // Positive
      sequence  voltage  in  Volts
32  Va2  =  (Va  -  %i*Vb)/2;
                                              // Negative
      sequence  voltage  in  Volts
33  Z11  =  (R1+%i*X1);
34  Z12  =   (((%i*Xm)*(R2/s+%i*X2))/(%i*Xm+R2/s+%i*X2));
35  Z1  =  Z11  +  Z12  ;
                                                      //
      Positive  sequence  impedance  in  Ohms
36  Z2  =  (R1+%i*X1)  +  (((%i*Xm)*(R2/(2-s)+%i*X2))/(%i*Xm
      +R2/(2-s)+%i*X2));      // Negative  sequence
      impedance  in  Ohms
37  Ia1  =  Va1/Z1;
                                                      //
      Positive  sequence  current  in  Amphere
38  I12  =  (Ia1*Z12)/(R2/s);
                                              // Positive
      sequence  current  in  Amphere
39  Ia2  =  Va2/Z2;
                                                      //
      Negative  sequence  current  in  Amphere
40  I22  =  (Ia2*Z2)/(R2/(2-s));
                                              // Negative
```

```
      sequence current in Amphere
41  T1 = 2*(abs(I12)^2)*R2/s;
                                              // Positive
      sequence torque in Newton-meter
42  T2 = 2*(abs(I22)^2)*R2/(2-s);
                                          // Negative sequence
        torque in Newton-meter
43  T = T1 - T2;
                                                            //
      Resultant torque in Newton-meter
44  Ia = Ia1 + Ia2;
                                                          //
      Line current in Amphere
45  Ib = (-%i*Ia1) + (%i*Ia2);
                                        // Line current
      in Amphere
46
47
48  // DISPLAY RESULTS
49
50  disp("EXAMPLE : 7.3: SOLUTION :-");
51  printf("\n (a) Resultant torque, T = %.2f N-m \n",T)
52  printf("\n (b) Phase currents (line currents), Ia =
      %.2f < %.2f A \n\n
                                            Ib = %.2f < %
      .2f \n",abs(Ia),atand(imag(Ia),real(Ia)),abs(Ib),
      atand(imag(Ib),real(Ib)))
53  printf("\n\n IN THE ABOVE PROBLEM ALL THE VALUES
      PRINTED IN THE TEXT BOOK ARE NOT ACCURATE, SO
      VALUE OF THE TORQUE AND LINE CURRENTS ARE
      DIFFERING, WHEN WE COMPARED TO THE TEXT BOOK
      ANSWERS FOR THE SAME. \n\n")
54  printf("\n IN EVERY CALCULATED PARAMETER IN THE TEXT
      BOOK SLIGHT VARIATION IS THERE AS WE COMPARED TO
      MANUAL CALCULATION ITS FROM POSITIVE SEQUENCE
      VOLTAGE (Va1) \n")
```

Scilab code Exa 7.4 To find the resultant torque

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
       GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.4
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 m = 2;                                          //
       Total number of phase in AC drag−cup servo Motor
17 p = 2;                                          //
       Number of poles
18 Va = 220;                                       //
       Operating Voltage of the servo Motor in Volts
19 R1 = 350;                                       //
       Circuit Parameter in Ohms
20 R2 = 250;                                       //
       Circuit Parameter in Ohms
21 X1 = 60;                                        //
       Circuit Parameter in Ohms
22 X2 = 50;                                        //
       Circuit Parameter in Ohms
23 Xm = 900;                                       //
```

```scilab
     Circuit  Parameter  in  Ohms
24  s = 0.3;                                               //
     Slip
25  p = 0.8;                                               //
     Ratio  of  the  control  winding  and  main  winding
     voltage
26
27
28  // CALCULATIONS
29
30  Va1 = (Va*(1+p))/2;
                                                          //
     Positive  sequence  voltage  in  Volts
31  Va2 = (Va*(1-p))/2;
                                                          //
     Negative  sequence  voltage  in  Volts
32  Z11 = (R1+%i*X1);
33  Z12 =  (((%i*Xm)*(R2/s+%i*X2))/(%i*Xm+R2/s+%i*X2));
34  Z1 = Z11 + Z12 ;
                                                          //
     Positive  sequence  impedance  in  Ohms
35  Z2 = (R1+%i*X1) + (((%i*Xm)*(R2/(2-s)+%i*X2))/(%i*Xm
     +R2/(2-s)+%i*X2));       // Negative  sequence
     impedance  in  Ohms
36  Ia1 = Va1/Z1;
                                                          //
     Positive  sequence  current  in  Amphere
37  I12 = (Ia1*Z12)/(R2/s);
                                                 // Positive
     sequence  current  in  Amphere
38  Ia2 = Va2/Z2;
                                                          //
     Negative  sequence  current  in  Amphere
39  I22 = (Ia2*Z2)/(R2/(2-s));
                                                 // Negative
     sequence  current  in  Amphere
40  T1 = 2*(abs(I12)^2)*R2/s;
                                                 // Positive
```

```
      sequence  torque  in  Newton−meter
41  T2 = 2*(abs(I22)^2)*R2/(2-s);
                                  // Negative  sequence
      torque  in  Newton−meter
42  T = T1 - T2;
                                                      //
      Resultant  torque  in  Newton−meter
43
44
45  // DISPLAY RESULTS
46
47  disp("EXAMPLE : 7.4: SOLUTION :−");
48  printf("\n (a) Resultant  torque , T = %.2 f N−m \n",T)
49  printf("\n\n IN  THE ABOVE PROBLEM ALL  THE VALUES
      PRINTED IN  THE TEXT BOOK ARE NOT ACCURATE, SO
      VALUE OF THE TORQUE AND LINE CURRENTS ARE
      DIFFERING WHEN WE COMPARED TO  THE TEXT BOOK
      ANSWERS FOR THE SAME. \n\n")
50  printf("\n IN  EVERY CALCULATED PARAMETER IN  THE TEXT
       BOOK SLIGHT VARIATION IS  THERE AS WE COMPARED TO
       MANUAL CALCULATION ITS FROM POSITIVE SEQUENCE
       IMPEDANCE  (Z1)  \n")
```

Scilab code Exa 7.5 To find speed and pf

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First  Impression  2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION  TO
      GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.5
```

```
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  R = 15;
        // Resistance of the fractional horse power AC
        series motor in Ohms
17  V = 230;
        // AC supply voltage in Volts
18  f = 50;
        // Frequency in Hertz
19  I = 1.2;
        // Motor current in Amphere
20  NDC = 2500;
        // Rotating speed of the Motor during DC
        Operation in RPM
21  L = 0.5;
        // Total inductance in Henry
22
23
24  // CALCUALTIONS
25
26  X = 2*%pi*f*L;

        // Reactance in Ohms
27  NAC = NDC * (sqrt(V^2-(I*X)^2)-(I*R)) / (V-(I*R));
                    // Rotating speed of the Motor
        during AC Operation in RPM
28  pf = sqrt(1-((I*X)/V)^2);
                                        // Power
        factor lagging
29
30
31  // DISPLAY RESULTS
32
```

```
33  disp("EXAMPLE : 7.5: SOLUTION :−");
34  printf("\n When the Motor operting at AC 230V, 50 Hz
        \n\n (a) NAC = %.f RPM \n",NAC)
35  printf("\n (b) Power factor = %.4f lagging \n",pf)
```

Scilab code Exa 7.6 To find current pf torque at rated condition and speed pf torque and efficiency at load current is halved

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
       GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.6
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 R = 1.4;
       // Total Resistance of the AC series motor in
       Ohms
17 V = 115;
       // supply voltage in Volts
18 f = 50;
       // Frequency in Hertz
19 N = 5000;
       // Rotating speed in RPM
20 X = 12;
```

```scilab
      // Total reactance in Ohms
21 P = 250;
      // Electrical power output in Watts
22 loss = 18;
      // Rotational losses in Watts
23
24
25 // CALCULATIONS
26
27 Pd = P + loss;
                                                //
      Mechanical power developed in Watts
28 // We know that Er = Pd/I and from phasor diagram in
       figure 7.11 page no. 501 V^2 = (Er+I*R)^2+(I*X)
      ^2, 115^2 = (268/I-1.4*I)^2+(12*I)^2, 13225*I^2 =
      71824+2.036*I^4-750.4*I^2+144*I^2, solving this
      we get 2.036*I^4-13831.4*I^2+71824 = 0, I
      ^4-6793.42*I^2+3577 = 0 this gives I = 2.28A or
      82.38A (The above calculation part is wrong )
29 i = poly ([3577 0 -6793.42 0 1],'x','coeff');
                          // Expression for the Current
      in Quadratic form
30 a = roots (i);

      // 4-Value of the current in Amphere
31 I = a(4,1);

      // Curent in Amphere neglecting higher value and
      negative value
32
33 pf_a = sqrt(1-((I*X)/V)^2);
                                                // Power
      factor lagging
34 Er_a = sqrt(V^2-(I*X)^2)-(I*R);
                                          // Rotational
      Voltage in Volts
35 T_a = (Er_a*I)/(2*%pi*N/60);
                                              // Developed
```

299

```
         torque in Newton-meter
36  Ih = I/2;

        // Current halved in Amphere
37  pf_b = sqrt(1-((Ih*X)/V)^2);
                                                // Power
      factor lagging when load current halved
38  Er_b = sqrt(V^2-(Ih*X)^2)-(Ih*R);
                                        // Rotational
      Voltage in Volts when load current halved
39  N2 = (N*Er_b*I)/(Er_a*Ih);
                                                // New speed
       in RPM when load current halved
40  T_b = (Er_b*Ih)/(2*%pi*N2/60);
                                        // Developed
      torque in Newton-meter when load current halved
41  eta = 100*(Er_b*Ih)/(V*Ih*pf_b);
                                        // Efficiency when
      load current halved
42
43
44  // DISPLAY RESULTS
45
46  disp("EXAMPLE : 7.6: SOLUTION :-");
47  printf("\n At rated condition, \n\n (a.1) Current, I
       = %.2f A \n",I)
48  printf("\n (a.2) Power factor = %.3f lagging \n",
      pf_a)
49  printf("\n (a.3) Developed torque = %.2f N-m \n",T_a
      )
50  printf("\n When load current halved (reduced to half
       ), \n\n (b.1) Speed, N2 = %.f RPM \n",N2)
51  printf("\n (b.2) Power factor = %.4f lagging \n",
      pf_b)
52  printf("\n (b.3) Developed torque = %.2f N-m \n",T_b
      )
53  printf("\n (b.4) Efficiency = %.1f percenatge \n",
      eta)
```

```
54  printf("\n From Calculation of the Current(I), rest
        all the Calculated values in the TEXT BOOK is
        WRONG because of the Current equation and its
        value both are WRONGLY calculated and the same
        used for the further Calculation part, so all the
         values are in the TEXT BOOK IS WRONG \n")
```

Scilab code Exa 7.7 To find line current pf and efficiency of motor

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
        GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.7
10
11  clear ; clc ; close ; // Clear the work space and
        console
12
13
14  // GIVEN DATA
15
16  V = 220;
        // supply voltage in Volts
17  f = 50;
        // Frequency in Hertz
18  p = 4;
        // Number of poles
19  Xm = 50;
        // Mutual reactance in Ohms
20  Rs = 0.4;
```

```
      // Resistance of stator windings in Ohms
21  Xs = 2.5;
      // Leakage reactance of stator windings in Ohms
22  Ra = 2.2;
      // Resistance of Armature windings in Ohms
23  Xa = 3.1;
      // Leakage reactance of armature windings in Ohms
24  loss = 30;
      // Rotational losses in Watts
25  N = 2000;
      // Motor running speed in RPM
26
27
28  // CALCULATIONS
29
30  Ns = (120*f)/p;

      // Synchronous speed in RPM
31  s = N/Ns;

      // Speed ratio
32  I1 = V/(2*Rs + 2*%i*Xs + 2*%i*Xm + (%i*Xm^2)*((s-%i)
      /(Ra+%i*Xa+%i*Xm)));// line current in Amphere
33  pf = cosd(atand(imag(I1),real(I1)));
                                          // Power factor
       lagging
34  I2 = (s-%i)*(%i*Xm*I1)/(Ra+%i*Xa+%i*Xm);
                                          // line current
      in Amphere
35  P1 = V*abs(I1)*cosd(atand(imag(I1),real(I1)));
                                  // Input power in Watts
36  Pm = P1 - 2*(abs(I1)^2)*Rs - (abs(I2)^2)*Ra;
                                  // Mechanical power
      developed in Watts
37  Po = Pm - loss;

      // output power in Watts
38  eta = 100*(Po/P1);
```

```
        // Efficiency
39
40
41  // DISPLAY RESULTS
42
43  disp("EXAMPLE : 7.7: SOLUTION :−");
44  printf("\n (a) Line currents, I1 = %.2f < %.2f A and
        I2 = %.2f < %.2f A \n",abs(I1),atand(imag(I1),
        real(I1)),abs(I2),atand(imag(I2),real(I2)))
45  printf("\n (b) Power factor = %.2f lagging \n",pf)
46  printf("\n (c) Efficiency = %.2f percentage \n",eta)
47  printf("\n\n    [ TEXT BOOK SOLUTION IS PRINTED
        WRONGLY ( I verified by manual calculation )]\n"
        );
48  printf("\n        WRONGLY PRINTED ANSWERS ARE :− (a)
        I1 = 3.37 < −42.78 A instead of %.2f < j(%.2f) A
        \n ",abs(I1),atand(imag(I1),real(I1)));
49  printf("\n                                    (b)
        I2 = 5.26 < −77.34 A instead of %.2f < j(%.2f) A
        \n ",abs(I2),atand(imag(I2),real(I2)));
50  printf("\n                                    (b)
        eta = 81.53 percent instead of %.2f percent  \n "
        ,eta)
51  printf("\n From Calculation of the I1, rest all the
        Calculated values in the TEXT BOOK is WRONG
        because of the I1 value is WRONGLY calculated and
         the same used for the further Calculation part \
        n")
```

Scilab code Exa 7.8 To find current and pf of the motor

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
```

```
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
      GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.8
10
11 clear ; clc ; close ; // Clear the work space and
      console
12
13
14 // GIVEN DATA
15
16 V = 220;
      // supply voltage in Volts
17 f = 50;
      // Frequency in Hertz
18 p = 4;
      // Number of poles
19 Xm = 60;
      // Mutual reactance in Ohms
20 Rs = 1.0;
      // Resistance of stator windings in Ohms
21 Xs = 6.0;
      // Leakage reactance of stator windings in Ohms
22 Ra = 2.5;
      // Resistance of Armature windings in Ohms
23 Xa = 6.0;
      // Leakage reactance of armature windings in Ohms
24 P_hp = 1;
      // Output power in HP
25 N = 1400;
      // Motor running speed in RPM
26 alpha = 15;
      // Brush displacement from the low-impedance
      position in degree
27
```

```
28  // CALCULATIONS
29
30  Ns = (120*f)/p;

        // Synchronous speed in RPM
31  s = N/Ns;

        // Speed ratio
32  I = V / (Rs + %i*(Xs+Xm) + (%i*Xm^2*cosd(alpha))*(s*
        sind(alpha)-(%i*cosd(alpha)))/(Ra+%i*(Xa+Xm)));
                                                        //
        Curent in Amphere
33  pf = cosd(atand(imag(I),real(I)));
                                                // Power
        factor lagging
34
35
36  // DISPLAY RESULTS
37
38  disp("EXAMPLE : 7.8: SOLUTION :-");
39  printf("\n (a) Currents, I = %.2f < %.2f A \n",abs(I
        ),atand(imag(I),real(I)))
40  printf("\n (b) Power factor = %.4f lagging \n",pf)
```

Scilab code Exa 7.9 To find no load slips

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
        GENERALIZED MACHINE THEORY
8
```

```scilab
9  // EXAMPLE : 7.9
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 E2 = 100;                                        // Per
       phase standstill EMF in Volts
17 Z2s = 0.025 + %i*0.08;                           // Rotor
       circuit impedance at standstill
18 E = 50;                                          //
       Injected EMF in Volts
19
20
21 // CALCULATIONS
22
23 I2 = 0;                                          //
       Assuming Current is zero
24 s1 = (E/E2)+(I2*Z2s)/E2;                         // Slip
       when injected EMF is opposite to the E2
25 s2 = (-E/E2)+(I2*Z2s)/E2;                        // Slip
       when injected EMF is phase with E2
26
27
28 // DISPLAY RESULTS
29
30 disp("EXAMPLE : 7.9: SOLUTION :−");
31 printf("\n (a) Slip when injected EMF is opposite to
       the E2, s = %.1f \n",s1)
32 printf("\n (b) Slip when injected EMF is phase with
       E2, s = %.1f \n",s2)
```

Scilab code Exa 7.10 To find synchronous linear speed per phase current and pf

```
1
2  // ELECTRICAL MACHINES
3  // R.K.Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
       GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.10
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 L = 1.0;
       // Length in Meter
17 S = 60;
       // Number of slots
18 f = 50;
       // Frequency in Hertz
19 v = 440;
       // Operating Volage of the Motor in Volts
20 V = 11.5;
       // Running speed of the motor in Meter/second
21 m = 3;
       // Number of phases
22 p = 8;
       // Total number of Poles
23
24
25 // CALCULATIONS
26
```

```
27  Vs = (2*L*f)/p;
                                                    //
        Synchronous linear speed in Meter/second
28  s = (Vs-V)/Vs;
                                                    //
        Linear slip
29  Vph = v/sqrt(3);
                                                    // Phase
        Voltage in Volts
30  Z1 = 6.0 + %i*5;
                                                    //
        Impedance in Ohms refer figure and page no. 526
31  Z2 = ((100*%i)*(5*%i+8.2/s))/(100*%i+5*%i+8.2/s);
              // Impedance in Ohms refer figure and page
        no. 526
32  Z = Z1 + Z2;
                                                    //
        Total Impedance in Ohms
33  I = Vph/Z;
                                                    //
        Per phase Current when Machine is running at 11.5
         m/s in Amphere
34  pf = cosd(atand(imag(I),real(I)));
                                // Power factor lagging
35
36
37  // DISPLAY RESULTS
38
39  disp("EXAMPLE : 7.10 : SOLUTION :-") ;
40  printf("\n (a) Synchronous linear speed, Vs = %.1f m
        /s \n ",Vs);
41  printf("\n (b) Per phase current when Machine is
        running at 11.5 m/s, I = %.2f < %.2f A \n",abs(I)
        ,atand(imag(I),real(I)))
```

Scilab code Exa 7.11 To find input pulse rate in pulses per second

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
       GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.11
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 s = 9;
       // Degree per step of the stepper motor
17 N = 200;
       // Rotation Speed of the Stepper motor in RPM
18
19
20 // CALCULATIONS
21
22 spr = 360/s;
       // Steps Per Revolution (360 is full revolution)
23 pps = (N*spr)/60;
                                            // Input
       pulse rate in pulses per second
24
25
26 // DISPLAY RESULTS
27
28 disp("EXAMPLE : 7.11: SOLUTION :-");
29 printf("\n (a) Input pulse rate is %.2f pulses per
```

```
        second \n",pps)
```

Scilab code Exa 7.13 To find torque and state whether force is positive or negative

```
1
2  // ELECTRICAL MACHINES
3  // R.K. Srivastava
4  // First Impression 2011
5  // CENGAGE LEARNING INDIA PVT. LTD
6
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
       GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.13
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 L1 = 1.1;
                                                    //
       Inductance in Henry
17 L2 = 1.07;
                                                    //
       Inductance in Henry
18 dtheta = 1;
                                                    //
       Rotor rotation in Mechanical degree
19 r = 0.10;
                                                    //
       Radius of the rotor in Meter
20 I = 20;
```

```
        // Coil  Current  in  Amphere
21
22
23  // CALCULATIONS
24
25  dl = L1-L2;
                                                    //
        Change  in  Inductance  of  one  of  its  stator  coils
        in  Henry
26  F = (I^2*dl)/(2*dtheta);
                                        // Force  on  the
        single  rotor  pole  in  Newton
27  T = F*r;
                                                                //
        Instantaneous  Torque  in  Newton−meter
28
29
30  // DISPLAY  RESULTS
31
32  disp("EXAMPLE : 7.13: SOLUTION :−");
33  printf("\n (a) Instantaneous  Torque, T = %.1f N–m \n
        \n",T)
34  printf("The  force  is  a  motoring  force  since
        inductance  of  the  coil  is  rising")
```

Scilab code Exa 7.14 To find positive sequence negative sequence zero sequence voltages

```
1
2  // ELECTRICAL  MACHINES
3  // R.K. Srivastava
4  // First  Impression  2011
5  // CENGAGE  LEARNING  INDIA  PVT.  LTD
6
```

```scilab
7  // CHAPTER : 7 : SPECIAL MOTORS AND INTRODUCTION TO
       GENERALIZED MACHINE THEORY
8
9  // EXAMPLE : 7.14
10
11 clear ; clc ; close ; // Clear the work space and
       console
12
13
14 // GIVEN DATA
15
16 Va = 220 * exp( %i * 0 * %pi/180);
                                          // Three phase in
       Volts
17 Vb = 230 * exp( %i * (-115) * %pi/180);
                                          //  Three phase in
       Volts
18 Vc = 250 * exp( %i * (-245) * %pi/180);
                                          //  Three phase in
       Volts
19
20
21 // CALCUALTIONS
22 // We know that operator :-
23
24 alpha = 1 * exp( %i * 120 * %pi/180);
25 alpha2 = 1 * exp( %i * (-120) * %pi/180);
26 Va0 = (Va+Vb+Vc)/3
                                                       //
       Zero sequence Voltage in Volts
27 Va1 = (Va+alpha*Vb+alpha2*Vc)/3
                                          // Positive
       sequence Voltage in Volts
28 Va2 = (Va+alpha2*Vb+alpha*Vc)/3
                                          // Negative
       sequence Voltage in Volts
29
30
```

```scilab
31  // DISPLAY RESULTS
32
33  disp("EXAMPLE : 7.14 : SOLUTION :-") ;
34  printf("\n (a) Zero sequence Voltage, Va0 = %.2f < %
           .2f V \n",abs(Va0),atand(imag(Va0),real(Va0)))
35  printf("\n (b) Positive sequence Voltage, Va1 = %.3f
           < %.2f V \n",abs(Va1),atand(imag(Va1),real(Va1))
           )
36  printf("\n (c) Negative sequence Voltage, Va1 = %.2f
           < %.1f V \n",abs(Va2),atand(imag(Va2),real(Va2))
           )
```