

Scilab Textbook Companion for
Electric Machines
by C. I. Hubert¹

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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 1

Magnetics Electromagnetic Forces Generated Voltage and Energy Conversion

Scilab code Exa 1.2 Computation of Current in the coil and Magnetic potential difference across R3 and Flux in R2

```
1 // Example 1.2
```

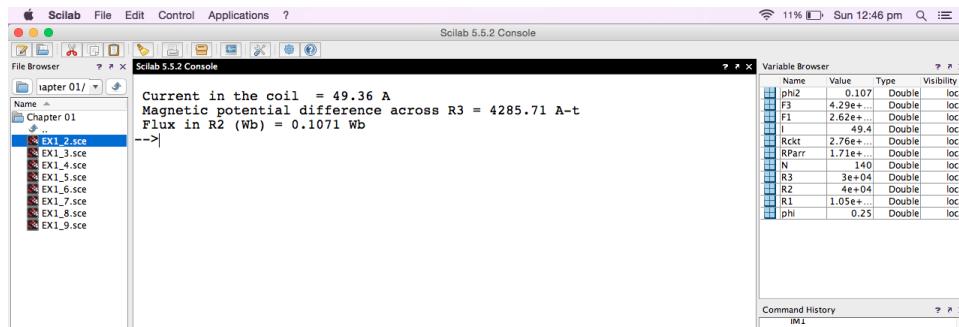


Figure 1.1: Computation of Current in the coil and Magnetic potential difference across R3 and Flux in R2

```

2 // Computation of (a) Current in the coil (b)
   Magnetic potential difference across R3
3 // (c) Flux in R2
4 //Page No. 13
5
6 clc;
7 clear all;
8 close;
9
10 // Given data
11 phi=0.250;                                // Flux in Wb
12 R1=10500;                                  // First magnetic circuit
   parameter
13 R2=40000;                                  // Second magnetic circuit
   parameter
14 R3=30000;                                  // Third magnetic circuit
   parameter
15 N=140;                                     // Number of turns of
   copper wire
16
17 // (a) Current in the coil
18 RParr=(R2*R3)/(R2+R3);                  // Parallel resistance
19 Rckt=R1+RParr;                            // Circuit resistance
20 I=(phi*Rckt)/N;
21
22 // (b) Magnetic potential difference across R3
23 F1=phi*R1;                                // Magnetic drop across
   R1
24 F3=(I*N)-F1;                             // Flux across R3
25
26 // (c) flux in R2
27 phi2=F3/R2;
28
29
30 // Display result on command window
31 printf("\n Current in the coil = %0.2f A ",I);
32 printf("\n Magnetic potential difference across R3 =
   %0.2f A-t ",F3);

```

```
33 printf("\n Flux in R2 (Wb) = %0.4f Wb ", phi2);
```

Scilab code Exa 1.3 Computation of hysteresis loss if the apparatus is connected to a 60 Hz source

```
1 // Example 1.3
2 // Computation of hysteresis loss if the apparatus
   is connected to a 60 Hz source
3 //Page No. 16
4
5 clc;
6 clear all;
7 close;
8
9 // Given data
10 V=240;                      // Rated voltage
11 F1=25;                       // Rated frequency
12 Ph2=846;                     // hysteresis loss
13 F2=60;                       // Source Frequency
14 Bmax1=0.62                   // Flux density is 62 percent
   of its rated value 1
15 Bmax2=1.0                     // Flux density is 62 percent
   of its rated value 2
16 Sc=1.4                        // Steinmetz exponents
17
18 // hysteresis loss if the apparatus is connected to
   a 60 Hz source
19 Ph1=Ph2*[(F2/F1)*(Bmax1/Bmax2)^Sc];
20 Ph1=Ph1/1000;
21
22 //Display result on command window
23 printf("\n Hysteresis loss if the apparatus is
   connected to a 60 Hz source = %0.2f kW", Ph1);
```

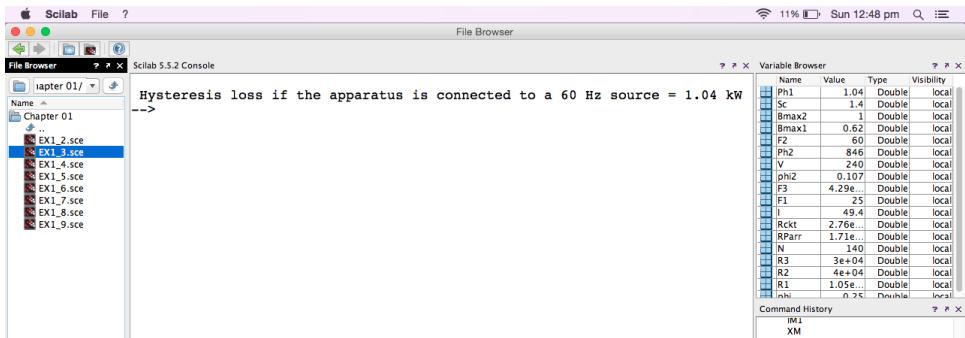


Figure 1.2: Computation of hysteresis loss if the apparatus is connected to a 60 Hz source



Figure 1.3: Computation of magnitude of the developed torque

Scilab code Exa 1.4 Computation of magnitude of the developed torque

```

1 // Example 1.4
2 // Computation of magnitude of the developed torque
3 // Page No. 21
4
5 clc;
```

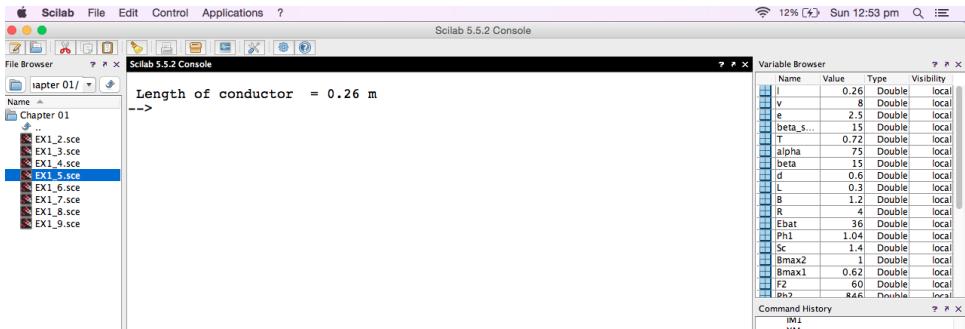


Figure 1.4: Computation of length of conductor

```

6 clear all;
7 close;
8
9 // Given data
10 Ebat=36;           // Battery voltage
11 R=4;               // Combined resistance of
                     the coil
12 B=0.23;            // Flux density
13 L=0.3;             // Length of the coil
14 d=0.60;            // Distance between centre
                     of each conductor and centre
15 // of each shaft
16 beta_skew=15        // Skew angle
17
18 // Magnitude of the developed torque
19 alpha=90-beta_skew;
20 I=Ebat/R;
21 T=2*B*I*(L*sind(alpha))*d; // Magnitude of the
                     developed torque
22
23 // Display result on command window
24 printf("\n Magnitude of the developed torque = %0.2f
                     N.m ",T);

```

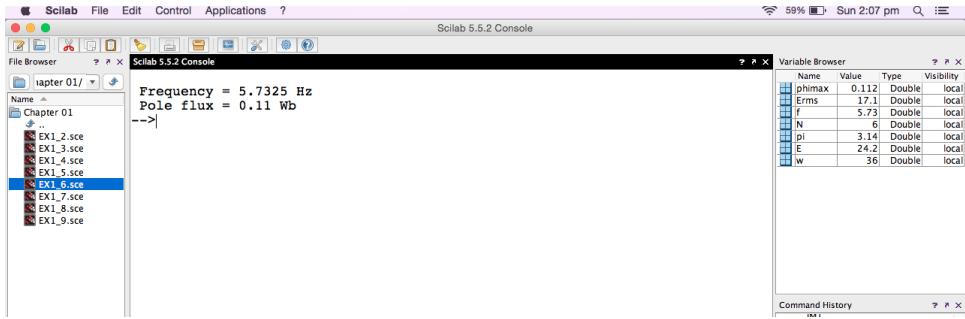


Figure 1.5: Computation of Frequency and Pole flux

Scilab code Exa 1.5 Computation of length of conductor

```

1 // Example 1.5
2 // Computation of length of conductor
3 // Page No. 25
4
5 clc;
6 clear all;
7 close;
8
9 // Given data
10 e=2.5;           // Voltage generated
11 B=1.2;           // Magnetic field
12 v=8.0;           // Speed
13
14 // Length of conductor (e=B*l*v)
15 l=e/(B*v);
16
17 //Display result on command window
18 printf("\n Length of conductor = %0.2f m ",l);

```

Scilab code Exa 1.6 Computation of Frequency and Pole flux

```
1 // Example 1.6
2 // Computation of (a) Frequency (b) Pole flux
3 // Page No. 27
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 w=36;           // Angular frequency
11 E=24.2;         // Voltage
12 pi=3.14;
13 N=6;            // Number of turns of rotor
14
15 // (a) frequency
16 f=w/(2*pi);    // Relation between angular
   frequency and frequency
17
18 // (b) pole flux
19 Erms=E/sqrt(2);
20 phimax = Erms/(4.44*f*N); // Relation to find
   pole flux
21
22
23 //Display result on command window
24 printf("\n Frequency = %0.4f Hz ",f);
25 printf("\n Pole flux = %0.2f Wb ",phimax);
```



Figure 1.6: Computation of eddy current loss if the apparatus is connected to a 60 Hz source

Scilab code Exa 1.7 Computation of eddy current loss if the apparatus is connected to a 60 Hz source

```

1 // Example 1.7
2 // Computation of eddy current loss if the
   apparatus is connected to a 60 Hz
3 //source
4 // Page No. 29
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 V=240;           // Rated voltage
12 F1=25;          // Rated frequency
13 Pe1=642;        // Eddy current loss
14 F2=60;          // Source Frequency
15 Bmax1=1.0       // Flux density is 62 percent
                  // of its rated value
16 Bmax2=0.62      // Flux density is 62 percent
                  // of its rated value
17
18 // Eddy current loss if the apparatus is connected
   to a 60 Hz source

```

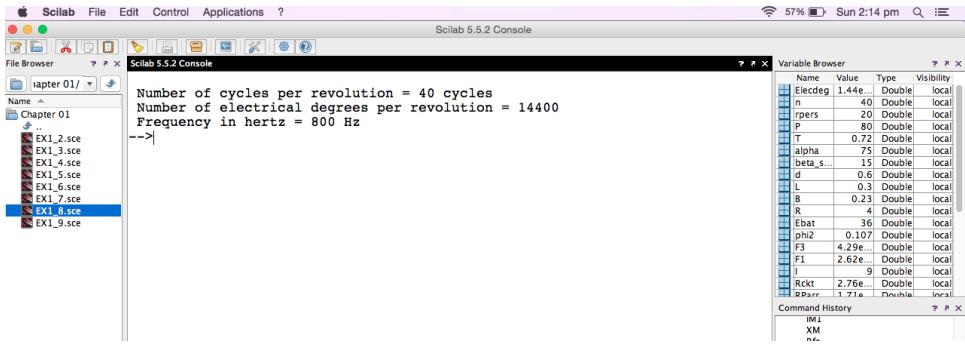


Figure 1.7: Computation of Number of cycles per revolution and Number of electrical degrees per revolution and Frequency in hertz

```

19 Pe2=Pe1*((F2/F1)^2*(Bmax2/Bmax1)^2);
20 Pe2=Pe2/1000;
21
22 // Display result on command window
23 printf("\n Eddy current loss if the apparatus is
           connected to a 60 Hz source = %0.2f kW ",Pe2);

```

Scilab code Exa 1.8 Computation of Number of cycles per revolution and Number of electrical degrees per revolution and Frequency in hertz

```

1 // Example 1.8
2 // Computation of (a) Number of cycles per
   revolution (b) Number of electrical
3 // degrees per revolution (c) Frequency in hertz
4 // Page No. 31
5
6 clc;
7 clear all;
8 close;
9

```

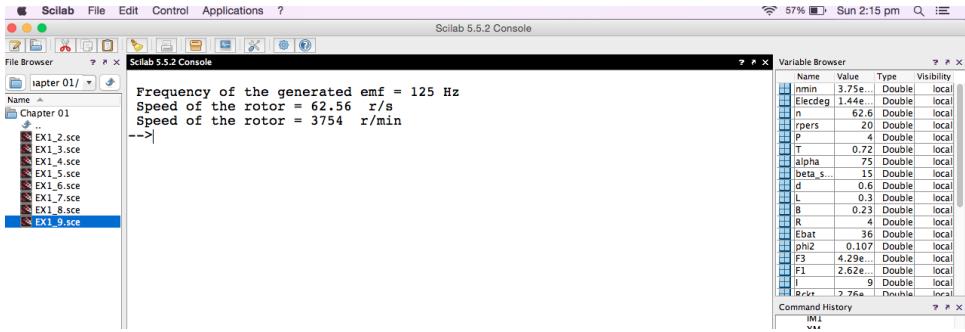


Figure 1.8: Computation of Frequency of the generated emf and Speed of the rotor

```

10 // Given data
11 P=80;                      // Number of poles
12 rpers=20;                   // Revolutions per second
13
14 // (a) Number of cycles per revolution
15 n=P/2;
16
17 // (b) Number of electrical degrees per revolution
18 Elecdeg=360*P/2;
19
20 // (c) Frequency in hertz
21 f=P*rpers/2;
22
23 // Display result on command window
24 printf("\n Number of cycles per revolution = %0.0f
cycles ",n);
25 printf("\n Number of electrical degrees per
revolution = %0.0f ",Elecdeg);
26 printf("\n Frequency in hertz = %0.0f Hz ",f);

```

Scilab code Exa 1.9 Computation of Frequency of the generated emf and Speed of the rotor

```
1 // Example 1.9
2 // Computation of (a) Frequency of the generated emf
   (b) Speed of the rotor
3 //Page No. 31
4
5 clc;
6 clear all;
7 close;
8
9 // Given data
10 Erms=100;           // Voltage generated in
                      armature coil
11 N=15;              // Number of turns in armature
                      coil
12 phimax=0.012;      // Flux per pole
13 P=4;               // Number of poles
14
15 // (a) frequency of the generated emf
16 f=Erms/(4.44*N*phimax);
17
18 // (b) speed of the rotor
19 n=2*f/P;
20 nmin=n*60;
21
22 //Display result on command window
23 printf("\n Frequency of the generated emf = %0.0 f Hz
          ",f);
24 printf("\n Speed of the rotor = %0.2 f r/s" ,n);
25 printf("\n Speed of the rotor = %0.0 f r/min" ,nmin);
```

Chapter 2

Transformer Principles

Scilab code Exa 2.1 Computation of peak value of sinusoidal flux in a transformer

```
1 // Example 2.1
2 // Computation of peak value of sinusoidal flux in a
   transformer
3 // Page No. 42
4
```

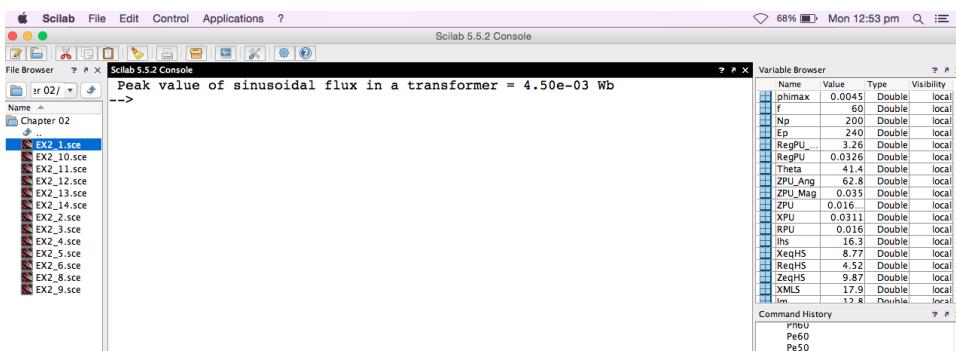


Figure 2.1: Computation of peak value of sinusoidal flux in a transformer

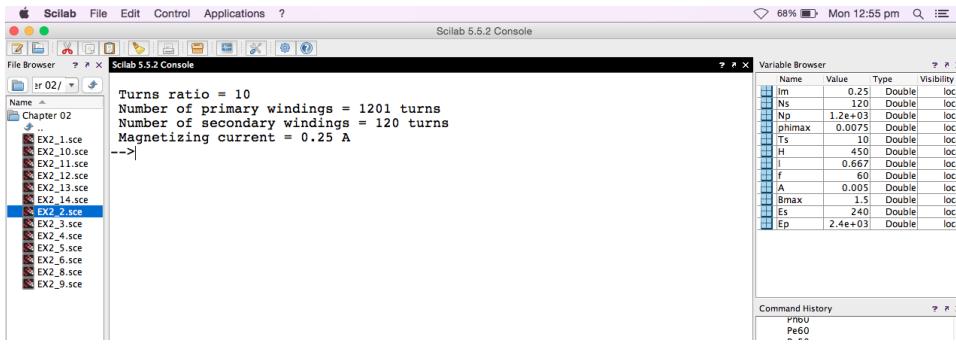


Figure 2.2: Computation of Turns ratio and Number of turns in each winding and Magnetizing current

```

5 clc;
6 clear all;
7 close;
8
9 // Given data
10 Ep=240;           // Voltage in primary coil
11 Np=200;          // Number of turns in primary
                    coil of transformer
12 f=60;            // Frequency of source
13
14 // Peak value of sinusoidal flux in a transformer
15 phimax=Ep/(4.44*Np*f);
16
17
18 //Display result on command window
19 //printf("\n Peak value of sinusoidal flux in a
        transformer = %0.4f WB ", phimax);
20
21
22 mprintf('Peak value of sinusoidal flux in a
        transformer = %3.2e Wb', phimax);

```

Scilab code Exa 2.2 Computation of Turns ratio and Number of turns in each winding and Magnetizing current

```
1 // Example 2.2
2 // Computation of (a) Turns ratio (b) Number of
   turns in each winding
3 // (c) Magnetizing current
4 // Page No. 42
5
6 clc;
7 clear;
8 close;
9
10 Ep=2400;           // Induced emf in primary
   winding
11 Es=240;            // Induced emf in primary
   winding
12 Bmax=1.5;          // Maximum flux density
13 A=50*10^-4;        // Cross section area
14 f=60;               // Frequency
15 l=0.667;            // Mean length of core
16 H=450;              // Magnetic field intensity
17
18
19 // (a) Turns ratio
20 Ts=Ep/Es;
21
22 // (b) Number of turns in each winding
23 phimax=Bmax*A;
24 Np=Ep/(4.44*f*phimax);           // Number of
   primary windings
25 Ns=Np/Ts;                     // Number of
   secondary windings
26
```

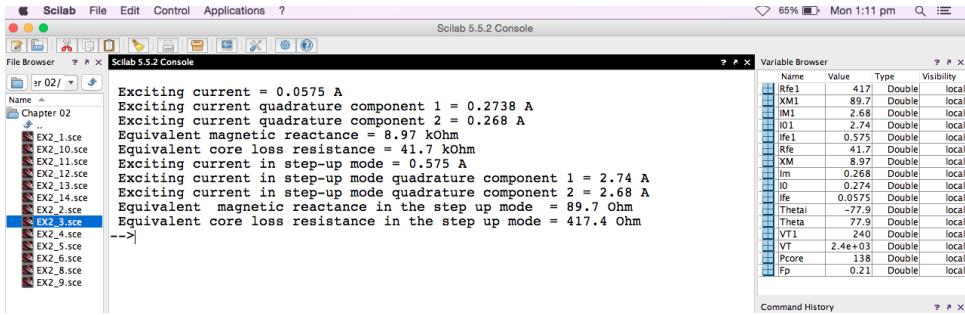


Figure 2.3: Computation of Exciting current and its quadrature components and Equalizing magnetic reactance and equivalent core loss resistance and Magnetizing current and repeat the calculations for the transformer in the step up mode

```

27 // (c) Magnetizing current
28 Im=H*l/Np;
29
30
31 //Display result on command window
32 printf("\n Turns ratio = %0.0f ",Ts);
33 printf("\n Number of primary windings = %0.0f turns
           ",Np);
34 printf("\n Number of secondary windings = %0.0f
           turns ",Ns);
35 printf("\n Magnetizing current = %0.2f A ",Im);

```

Scilab code Exa 2.3 Computation of Exciting current and its quadrature components and Equalizing magnetic reactance and equivalent core loss resistance and Magnetizing current and repeat the calculations for the transformer in the step up mode

```

1 // Example 2.3
2 // Computation of (a) Exciting current and its

```

```

        quadrature components
3 // (b) Equalizing magnetic reactance and equivalent
   core loss resistance
4 // (c) Magnetizing current (d) repeat (a) and (b) for
   the transformer in the
5 // step up mode
6 //Page No. 44
7
8 clc;
9 clear;
10 close;
11
12 Fp=0.210;           // Power factor
13 Pcore=138;          // Active power
14 VT=2400;            // Voltage applied to
   primary
15 VT1=240;            // 240-V primary voltage --
   Second case
16
17
18 // (a) Exciting current and its quadrature components
19 Theta=acosd(Fp);    // Angle
20 Thetai=-Theta;       // As phase angle of
   applied voltage is zero
21 Ife=Pcore/VT;        // Exciting current
22 I0=Ifc/Fp;           // Quadrature component
23 Im=tand(Thetai)*Ifc; // Quadrature component
24 Im=Im*-1;
25
26
27 // (b) Equalizing magnetic reactance and equivalent
   core loss resistance
28 XM=VT/Im;            // Magnetic reactance
29 Rfe=VT/Ifc;           // Core-loss resistance
30 XM=XM/1000;
31 Rfe=Rfe/1000;
32 // (c) Magnetizing current
33 Ife1=Pcore/VT1;       // Exciting current

```

```

34 I01=Ife1/cosd(Theta1);
35 IM1=tand(Theta1)*Ife1;      // Quadrature component
36 IM1=IM1*-1;
37
38 // (d) repeat (a) and (b) for the transformer in the
   step up mode
39 XM1=VT1/IM1;                // Magnetizing reactance
40 Rfe1=VT1/Ife1;              // Core-loss resistance
41
42
43
44 // Display result on command window
45 printf("\n Exciting current = %0.4f A ",Ife);
46 printf("\n Exciting current quadrature component 1 =
   %0.4f A ",I0);
47 printf("\n Exciting current quadrature component 2 =
   %0.3f A ",Im);
48 printf("\n Equivalent magnetic reactance = %0.2f
   kOhm ",XM);
49 printf("\n Equivalent core loss resistance = %0.1f
   kOhm ",Rfe);
50 printf("\n Exciting current in step-up mode = %0.3f
   A ",Ife1);
51 printf("\n Exciting current in step-up mode
   quadrature component 1 = %0.2f A ",I01);
52 printf("\n Exciting current in step-up mode
   quadrature component 2 = %0.2f A ",IM1);
53 printf("\n Equivalent magnetic reactance in the
   step up mode = %0.1f Ohm ",XM1);
54 printf("\n Equivalent core loss resistance in the
   step up mode = %0.1f Ohm ",Rfe1);

```

Scilab code Exa 2.4 Computation of Secondary voltage and Load current

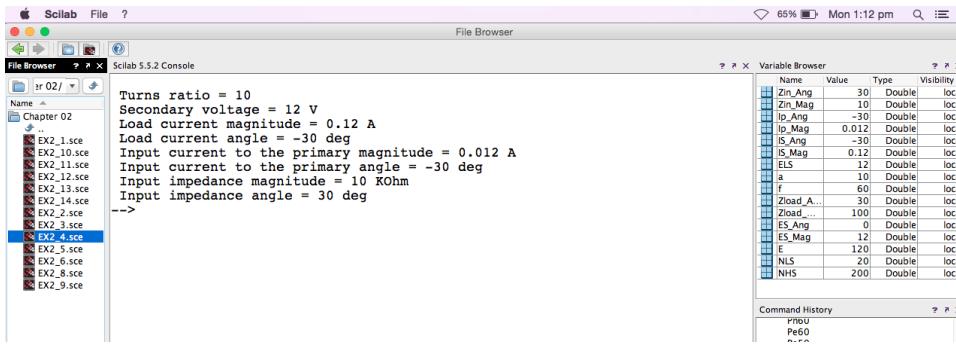


Figure 2.4: Computation of Secondary voltage and Load current and Input current to the primary and Input impedance looking into the primary terminals

and Input current to the primary and Input impedance looking into the primary terminals

```

1 // Example 2.4
2 // Computation of (a) Secondary voltage (b) Load
   current
3 // (c) Input current to the primary (d) Input
   impedance looking into the primary terminals
4 // Page No. 51
5
6 clc;
7 clear;
8 close;
9
10 NHS=200;           // Number of turns in primary
11 NLS=20;             // Number of turns in
                      secondary
12 E=120;              // Primary voltage magnitude
13 ES_Mag=12;          // Secondary voltage
                      magnitude
14 ES_Ang=0;            // Secondary voltage angle
15 Zload_Mag=100;       // Load magnitude
16 Zload_Ang=30;        // Load angle
17 f=60;                // Frequency

```

```

18
19 // (a) Secondary voltage
20 a=NHS/NLS;
21 ELS=E/a;
22
23 // (b) Load current
24 IS_Mag=ES_Mag/Zload_Mag;           // Load current
   magnitude
25 IS_Ang=ES_Ang - Zload_Ang;        // Load current
   angle
26
27 // (c) Input current to the primary
28 Ip_Mag=IS_Mag/a;                  // Input current to
   the primary magnitude
29 Ip_Ang=IS_Ang;                   // Input current to
   the primary angle
30
31 // (d) Input impedance looking into the primary
   terminals
32 Zin_Mag=a^2*Zload_Mag;           // Input impedance
   magnitude
33 Zin_Ang=Zload_Ang;               // Input impedance
   angle
34 Zin_Mag=Zin_Mag/1000;
35
36 // Display result on command window
37 printf("\n Turns ratio = %0.0f ",a);
38 printf("\n Secondary voltage = %0.0f V", ELS);
39 printf("\n Load current magnitude = %0.2f A", IS_Mag)
   ;
40 printf("\n Load current angle = %0.0f deg", IS_Ang);
41 printf("\n Input current to the primary magnitude =
   %0.3f A", Ip_Mag);
42 printf("\n Input current to the primary angle = %0.0
   f deg", Ip_Ang);
43 printf("\n Input impedance magnitude = %0.0f KOhm",
   Zin_Mag);
44 printf("\n Input impedance angle = %0.0f deg",

```

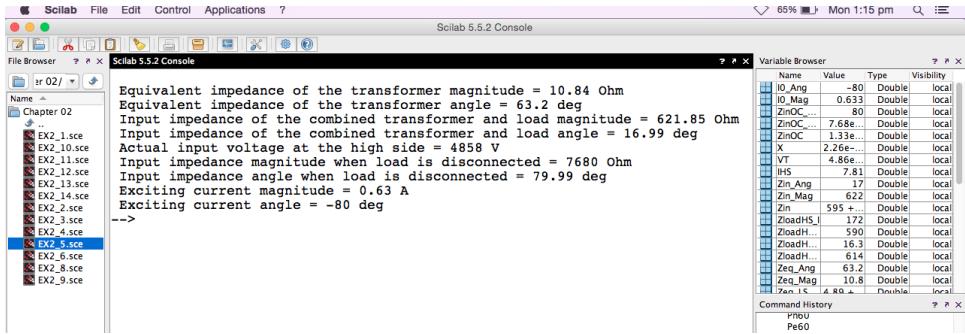


Figure 2.5: Computation of Equivalent impedance of the transformer referred to the high side and Input impedance of the combined transformer and load and Actual input voltage at the high side and Input impedance if the load is disconnected and Exciting current

Zin_Ang);

Scilab code Exa 2.5 Computation of Equivalent impedance of the transformer referred to the high side and Input impedance of the combined transformer and load and Actual input voltage at the high side and Input impedance if the load is disconnected and Exciting current

```

1 // Example 2.5
2 // Computation of (a) Equivalent impedance of the
3 // transformer referred to the
4 // high side (b) Input impedance of the combined
5 // transformer and load (C) Actual
6 // input voltage at the high side (d) Input
7 // impedance if the load is disconnected
8 // (e) Exciting current for the conditions in (d)
9 // Page No. 60
10
11 clc;
12 clear;

```

```

10 close;
11
12 // Given data
13 S=75000;                                // Transformer ratings
14 VLS=240;                                 // Low side voltage magnitude
15 PF=0.96;                                // Lagging power factor
16 VLS_Ang=0;                               // Low side voltage angle
17 VL=240;                                  // Load voltage
18 VHS=4800;                                // High side voltage
19 RHS=2.488;                               // High side resistance
20 RLS=0.00600;                            // Low side resistance
21 XHS=4.8384;                             // High side reactance
22 XLS=0.0121;                            // Low side reactance
23 Rfe=44202;                             // High side resistance
24 Xm=7798.6;                             // High side reactance
25
26
27 // (a) Equivalent impedance of the transformer
   referred to the
28 // high side
29 ILS=S*1/2/VLS;                           // Delivering one-
   half rated load
30 Theta=acosd(PF);                         // Angle
31 ThetaI=0-Theta;
32 ZloadLS_Mag=VLS/ILS;                     // Low side
   impedance magnitude
33 ZloadLS_Ang=VLS_Ang-ThetaI;              // Low side
   impedance angle
34
35 a=VHS/VL;                               // Ratio of High
   side and low side voltages
36 Zeq_LS=RHS+a^2*RLS+%i*(XHS+a^2*XLS)
37
38 // Complex to Polar form...
39
40 Zeq_Mag=sqrt(real(Zeq_LS)^2+imag(Zeq_LS)^2);
   // Magnitude part
41 Zeq_Ang= atan(imag(Zeq_LS),real(Zeq_LS))*180/%pi;

```

```

        // Angle part
42
43 // (b) Input impedance of the combined transformer
   and load
44 ZloadHS_Mag=a^2*ZloadLS_Mag;           // High side
   impedance magnitude
45 ZloadHS_Ang=ZloadLS_Ang;               // High side
   impedance angle
46
47 // Polar to Complex form
48
49 ZloadHS_R=ZloadHS_Mag*cos(-ZloadHS_Ang*pi/180); // Real part of complex number
50 ZloadHS_I=ZloadHS_Mag*sin(ZloadHS_Ang*pi/180); // Imaginary part of complex number
51 Zin=ZloadHS_R+%i* ZloadHS_I+Zeq_LS;          // Input impedance
52 // Complex to Polar form...
53
54 Zin_Mag=sqrt(real(Zin)^2+imag(Zin)^2);       // Magnitude part
55 Zin_Ang= atan(imag(Zin),real(Zin))*180/pi;    // Angle part
56
57 // (c) Actual input voltage at the high side
58 IHS=ILS/a;                                     // High side current
59 VT=IHS*Zin_Mag;
60
61 // (d) Input impedance if the load is disconnected
62 X=(1/Rfe)+(1/Xm*i);
63 ZinOC=1/X;
   // Input impedance
64 ZinOC_Mag=sqrt(real(ZinOC)^2+imag(ZinOC)^2); // Magnitude part
65 ZinOC_Ang= atan(imag(ZinOC),real(ZinOC))*180/pi; // Angle part
66 ZinOC_Ang=ZinOC_Ang*-1;
67

```

```

68 // (e) Exciting current for the conditions in (d)
69 I0_Mag=VT/ZinOC_Mag; // Magnitude of
    current
70 I0_Ang=0-ZinOC_Ang; // Angle of current
71
72 // Display result on command window
73 printf("\n Equivalent impedance of the transformer
        magnitude = %0.2f Ohm ",Zeq_Mag);
74 printf("\n Equivalent impedance of the transformer
        angle = %0.1f deg ",Zeq_Ang);
75 printf("\n Input impedance of the combined
        transformer and load magnitude = %0.2f Ohm ",
        Zin_Mag);
76 printf("\n Input impedance of the combined
        transformer and load angle = %0.2f deg ",Zin_Ang)
        ;
77 printf("\n Actual input voltage at the high side =
        %0.0f V", VT);
78 printf("\n Input impedance magnitude when load is
        disconnected = %0.0f Ohm",ZinOC_Mag);
79 printf("\n Input impedance angle when load is
        disconnected = %0.2f deg",ZinOC_Ang);
80 printf("\n Exciting current magnitude = %0.2f A",
        I0_Mag);
81 printf("\n Exciting current angle = %0.0f deg",
        I0_Ang);

```

Scilab code Exa 2.6 Computation of a Equivalent input impedance of the transformer and load combination and Primary current when 2400V is supplied to primary and Voltage across the load

```

1 // Example 2.6
2 // Computation of (a) Equivalent input impedance of

```

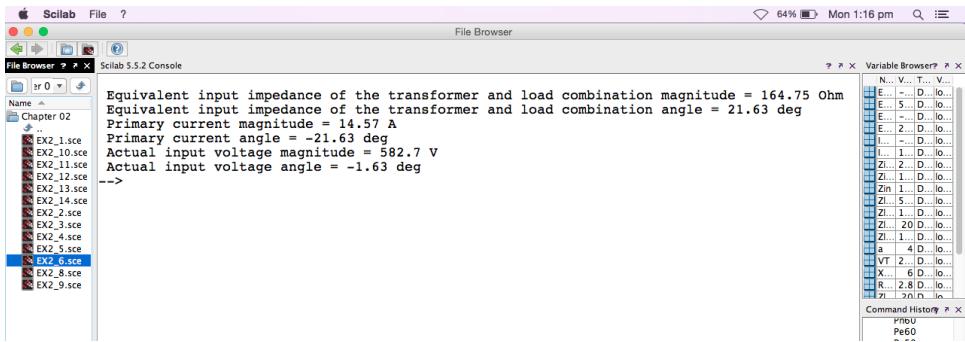


Figure 2.6: Computation of a Equivalent input impedance of the transformer and load combination and Primary current when 2400V is supplied to primary and Voltage across the load

```

the transformer and load
3 // combination (b) Primary current when 2400V is
   supplied to primary
4 // (C) Voltage across the load
5 // Page No. 61
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 S=37500;           // Transformer ratings
13 VHS=2400;          // High side voltage
14 VLS=600;           // Low side voltage magnitude
15 ZloadLS_Mag=10;    // Low side load impedance
                     magnitude
16 ZloadLS_Ang=20;    // Low side load impedance
                     angle
17 Req=2.8;           // Equivalent resistance
18 Xeq=6;              // Equivalent reactance
19 VT=2400;            // Primary voltage supplied
20
21 // (a) Equivalent input impedance of the transformer
   and load combination

```

```

22 a=VHS/VLS;                                // Ratio of High
   side and low side voltages
23 ZloadHS_Mag=a^2*ZloadLS_Mag;             // High side load
   impedance magnitude
24 ZloadHS_Ang=ZloadLS_Ang;                 // High side load
   impedance angle
25 // Polar to Complex form
26 ZloadHS_R=ZloadHS_Mag*cos(-ZloadHS_Ang*pi/180); // Real part of complex number
27 ZloadHS_I=ZloadHS_Mag*sin(ZloadHS_Ang*pi/180); // Imaginary part of complex number
28 Zin=Req+%i*Xeq+ZloadHS_R+%i*ZloadHS_I;
29 // Complex to Polar form...
30
31 Zin_Mag=sqrt(real(Zin)^2+imag(Zin)^2); // Magnitude part
32 Zin_Ang = atan(imag(Zin),real(Zin))*180/pi; // Angle part
33
34 // (b) Primary current when 2400V is supplied to primary
35 IHS_Mag=VT/Zin_Mag;                      // Primary current magnitude
36 IHS_Ang=0-Zin_Ang;                       // Primary current angle
37
38 // (c) Voltage across the load
39 EHS_Mag= IHS_Mag*a^2*ZloadLS_Mag; // Magnitude of voltage across reflected load
40 EHS_Ang=IHS_Ang+ZloadLS_Ang;           // Angle of voltage across reflected load
41
42 ELS_Mag=EHS_Mag/a;                     // Magnitude of actual voltage across real load
43 ELS_Ang=EHS_Ang;                      // Angle of actual voltage across real load
44
45

```

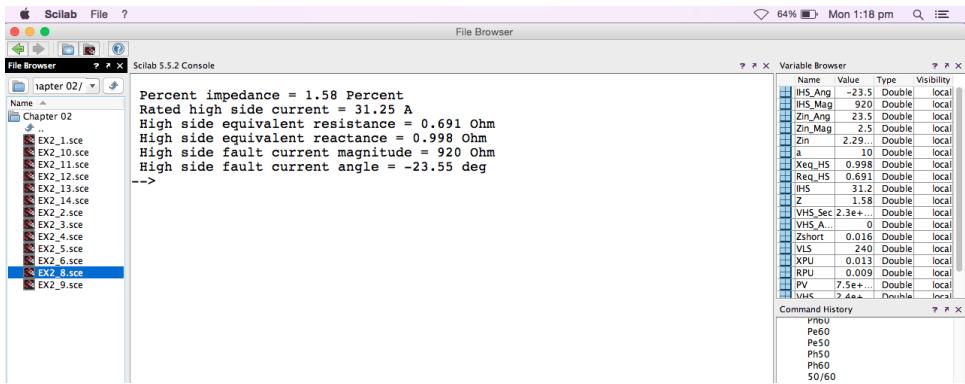


Figure 2.7: Computation of Percent impedance and Rated high side current and Equivalent resistance and reactance referred to the high side and High side fault current

```

46 //Display result on command window
47 printf("\n Equivalent input impedance of the
        transformer and load combination magnitude = %0.2f Ohm ",Zin_Mag);
48 printf("\n Equivalent input impedance of the
        transformer and load combination angle = %0.2f deg ",Zin_Ang);
49 printf("\n Primary current magnitude = %0.2f A ",IHS_Mag);
50 printf("\n Primary current angle = %0.2f deg ",IHS_Ang);
51 printf("\n Actual input voltage magnitude = %0.1f V",
        , ELS_Mag);
52 printf("\n Actual input voltage angle = %0.2f deg",ELS_Ang);

```

Scilab code Exa 2.8 Computation of Percent impedance and Rated high side current and Equivalent resistance and reactance referred to the high side

and High side fault current

```
1 // Example 2.8
2 // Computation of (a) Percent impedance (b) Rated
3 // high side current
4 // (c) Equivalent resistance and reactance referred
5 // to the high side
6 // (d) High side fault current if an accidental
7 // short circuit of 0.016 Ohm
8 // occurs at secondary when 230V impressed across
9 // the primary
10 // Page No. 66
11
12 // Given data
13 R=0.9;                      // Percent resistance
14 X=1.3;                      // Percent reactance
15 VHS=2400;                   // High side voltage
16 PV=75000;                   // Transformer power rating
17 RPU=0.009                     // Per unit resistance
18 XPU=0.013                     // Per unit reactance
19 VLS=240;                     // Low side voltage
20 Zshort=0.016;                // Short circuit resistance
21 VHS_Ang=0;                   // High side voltage angle
22 VHS_Sec=2300;                // Secondary high side
23 voltage
24 // (a) Percent impedance
25 Z=sqrt(R^2+X^2);
26
27 // (b) Rated high side current
28 IHS=PV/VHS;
29
30 // (c) Equivalent resistance referred to the high
31 side
```

```

31 Req_HS=RPU*VHS/IHS;
32 // Equivalent reactance referred to the high side
33 Xeq_HS=XPU*VHS/IHS;
34
35 // (d) High side fault current
36 a=VHS/VLS; // Ratio of
               High side and low side voltages
37 Zin=Req_HS+%i*Xeq_HS+a^2*Zshort; // Input
               impedance
38 Zin_Mag=sqrt(real(Zin)^2+imag(Zin)^2); // Magnitude part of input impedance
39 Zin_Ang= atan(imag(Zin),real(Zin))*180/%pi; // Angle part
40 IHS_Mag=VHS_Sec/Zin_Mag; // High
               side current magnitude
41 IHS_Ang=VHS_Ang-Zin_Ang;
42
43
44 // Display result on command window
45 printf("\n Percent impedance = %0.2f Percent ",Z);
46 printf("\n Rated high side current = %0.2f A", IHS);
47 printf("\n High side equivalent resistance = %0.3f
               Ohm",Req_HS);
48 printf("\n High side equivalent reactance = %0.3f
               Ohm",Xeq_HS);
49 printf("\n High side fault current magnitude = %0.0
               f Ohm",IHS_Mag);
50 printf("\n High side fault current angle = %0.2f
               deg",IHS_Ang);

```

Scilab code Exa 2.9 Computation of Transformer regulation and Secondary voltage when the load is disconnected and Input primary voltage

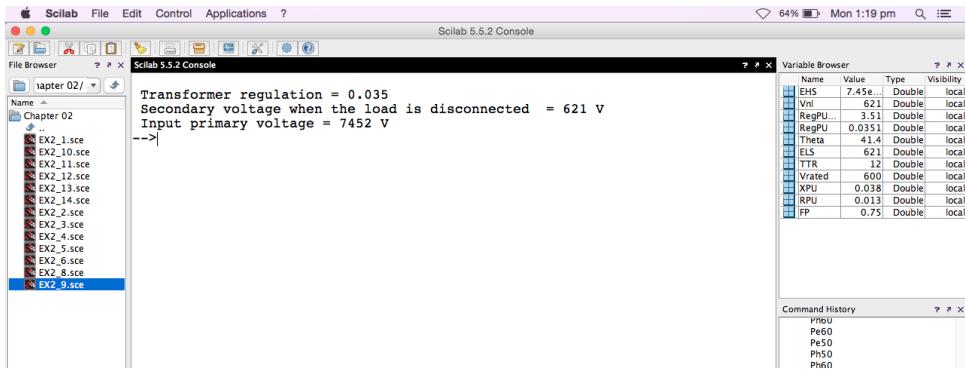


Figure 2.8: Computation of Transformer regulation and Secondary voltage when the load is disconnected and Input primary voltage

```

1 // Example 2.9
2 // Computation of (a) Transformer regulation (b)
3 // Secondary voltage when the
4 // load is disconnected (c) Input primary voltage
5 // Page No. 69
6
7 clc;
8 clear;
9
10 // Given data
11 FP=0.75 // Power-factor lagging
12 RPU=0.013; // Percent resistance
13 XPU=0.038; // Percent reactance
14 Vrated=600; // Rated voltage of
15 // transformer
16 TTR=12; // Transformer turns ratio
17 // (7200/600)
18 ELS=621; // Low side voltage
19
20 // (a) Transformer regulation
21 Theta=acosd(FP);

```

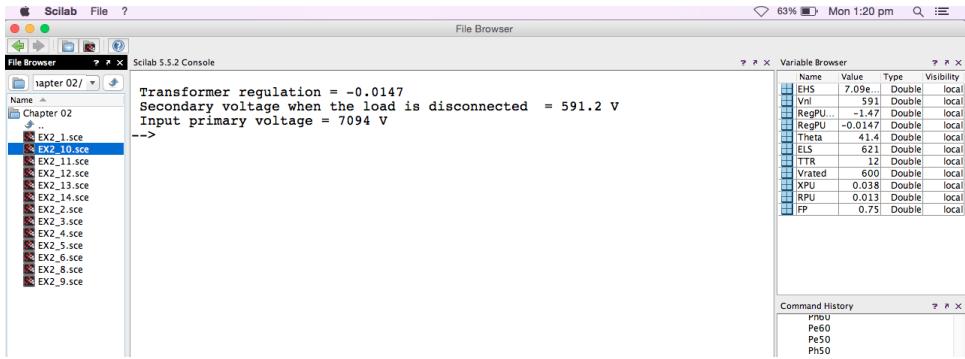


Figure 2.9: Computation of Transformer regulation and Secondary voltage when the load is disconnected and Input primary voltage

```

22 // Transformer regulation
23 RegPU=sqrt( ( (RPU+FP)^2)+ ((XPU+sind(Theta))^2))
    -1;
24 // Transformer regulation in percentage
25 RegPU_Per=RegPU*100;
26
27 // (b) Secondary voltage when the load is
    disconnected
28 Vnl=(RegPU*Vrated)+Vrated;
29
30 // (c) Input primary voltage
31 EHS=ELS*TTR;
32
33 // Display result on command window
34 printf("\n Transformer regulation = %0.3f ",RegPU);
35 printf("\n Secondary voltage when the load is
    disconnected = %0.0f V", Vnl);
36 printf(" \n Input primary voltage = %0.0f V",EHS);

```

Scilab code Exa 2.10 Computation of Transformer regulation and Secondary voltage when the load is disconnected and Input primary voltage

```
1 // Example 2.10
2 // Computation of (a) Transformer regulation (b)
3 // Secondary voltage when the
4 // load is disconnected (c) Input primary voltage
5 // Page No. 70
6
7 clc;
8 clear;
9
10 // Given data
11 FP=0.75 // Power-factor leading
12 RPU=0.013; // Percent resistance
13 XPU=0.038; // Percent reactance
14 Vrated=600; // Rated voltage of
15 // transformer
16 TTR=12; // Transformer turns ratio
17 // (7200/600)
18 ELS=621; // Low side voltage
19
20 // (a) Transformer regulation
21 Theta=acosd(FP);
22 // Transformer regulation
23 RegPU=sqrt( ((RPU+FP)^2)+ ((XPU-sind(Theta))^2))
24 -1;
25 // Transformer regulation in percentage
26 RegPU_Per=RegPU*100;
27 // (b) Secondary voltage when the load is
28 // disconnected
29 Vnl=(RegPU*Vrated)+Vrated;
30 // (c) Input primary voltage
```

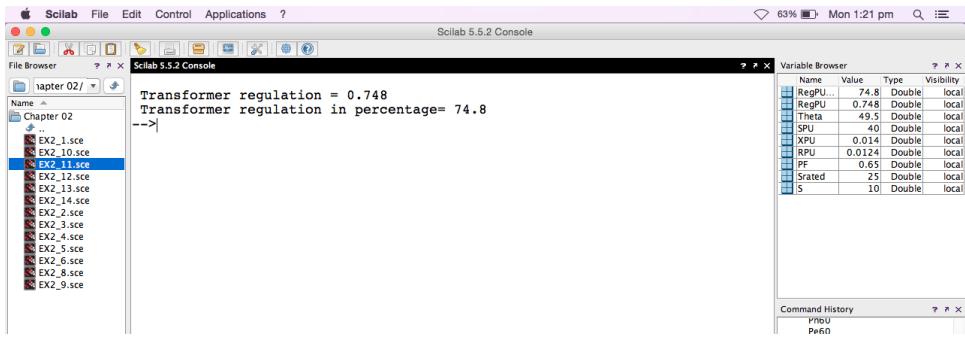


Figure 2.10: Computation of transformer regulation

```

31
32 EHS=Vnl*TTR ;
33
34 // Display result on command window
35 printf("\n Transformer regulation = %0.4f ",RegPU);
36 printf("\n Secondary voltage when the load is
            disconnected = %0.1f V", Vnl);
37 printf("\n Input primary voltage = %0.0f V",EHS);

```

Scilab code Exa 2.11 Computation of transformer regulation

```

1 // Example 2.11
2 // Computation of transformer regulation
3 // Page No. 71
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 S=10;                      // Transformer actual rating
                                10KVA

```

```

11 Srated=25;           // Rated 25KVA
12 PF=0.65;             // Power factor lagging
13 RPU=0.0124;          // Percent resistance drop
14 XPU=0.014;           // Percent reactance drop
15
16 // Transformer regulation
17 SPU=S/Srated;
18 SPU=SPU*100;
19 Theta=acosd(PF);
20 // Transformer regulation
21 RegPU=sqrt( ( (RPU*SPU+PF)^2)+ ((XPU*SPU+sind(Theta
    ))^2))-1;
22 // Transformer regulation in percentage
23 RegPU_Per=RegPU*100;
24
25 // Display result on command window
26 printf("\n Transformer regulation = %0.3f ",RegPU);
27 printf("\n Transformer regulation in percentage= %0
    .1f ",RegPU_Per);
28
29 // Answer varies due to round off errors

```

Scilab code Exa 2.12 Computation of Core loss and Core loss if operated at rated current and reduced power factor from 375V 50 HZ supply and Overall efficiency and Efficiency if the load is disconnected

```

1 // Example 2.12
2 // Computation of (a) Core loss (b) Core loss if
   operated at rated current and
3 // 0.860 power factor from 375V, 50 HZ supply (c)
   Efficiency for condition in (b)
4 // (d) Efficiency if the load is disconnected
5 // Page No. 72

```

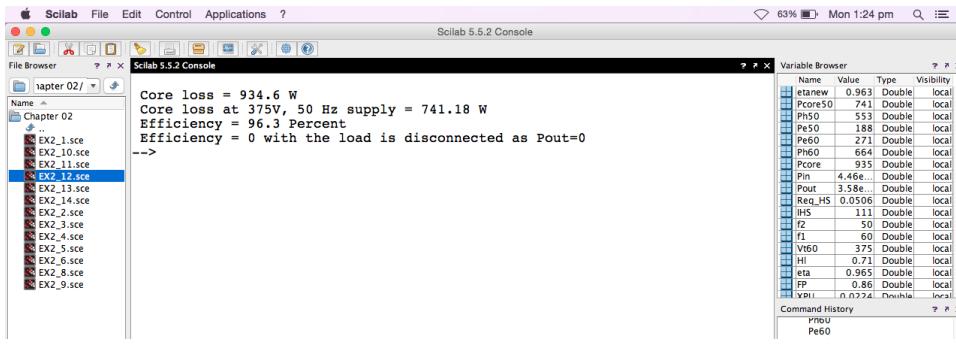


Figure 2.11: Computation of Core loss and Core loss if operated at rated current and reduced power factor from 375V 50 HZ supply and Overall efficiency and Efficiency if the load is disconnected

```

6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 Srated=50000; // Transformer power
13 rating
14 VHS=450; // High side voltage
15 RPU=0.0125; // Percent resistance
16 XPU=0.0224; // Percent reactance
17 FP=0.86; // Power factor lagging
18 eta=0.965 // Efficiency
19 H1=0.71 // Hysteresis loss
20 Vt60=375 // Supply voltage
21 f1=60; // Transformer frequency
22 f2=50; // Supply frequency
23
24 // (a) Core loss
25 IHS=Srated/VHS;
26 // Using high-side values
27 Req_HS=RPU*VHS/IHS; // Equivalent high-
side resistance

```

```

28 Pout=Srated*FP;                      // Output power
29 Pin=Pout/eta;                        // Input power
30 Pcore=Pin-Pout-(IHS^2*Req_HS)      // Core loss
31
32 // (b) Core loss if operated at rated current and
   0.860 power factor from
33 // 375V, 50 HZ supply
34 Ph60=H1*Pcore;                      // Hysteresis loss
35 Pe60=Pcore-Ph60;                    // Eddy current loss
36 Pe50=Pe60*(Vt60/VHS)^2;            // Eddy current loss
37 Ph50=Ph60*(f2/f1)*(Vt60/VHS*f1/f2)^1.6;
38 Pcore50=Pe50+Ph50;                  // Core loss
39
40 // (c) Efficiency
41 Pout=Vt60*IHS*FP;                  // Output power
42 etanew=Pout/(Pout+Pcore50+IHS^2*Req_HS);
43
44 // (d) Efficiency with the load is disconnected
45
46 // Display result on command window
47 printf("\n Core loss = %0.1f W", Pcore);
48 printf("\n Core loss at 375V, 50 Hz supply = %0.2f W
   ", Pcore50);
49 printf("\n Efficiency = %0.1f Percent", etanew*100);
50 printf("\n Efficiency = 0 with the load is
   disconnected as Pout=0" )

```

Scilab code Exa 2.13 Determine Efficiency at rated load and 80 percent power factor and 70 percent load and 80 percent power factor

```

1 // Example 2.13
2 // Determine (a) Efficiency at rated load and 80%
   power factor

```

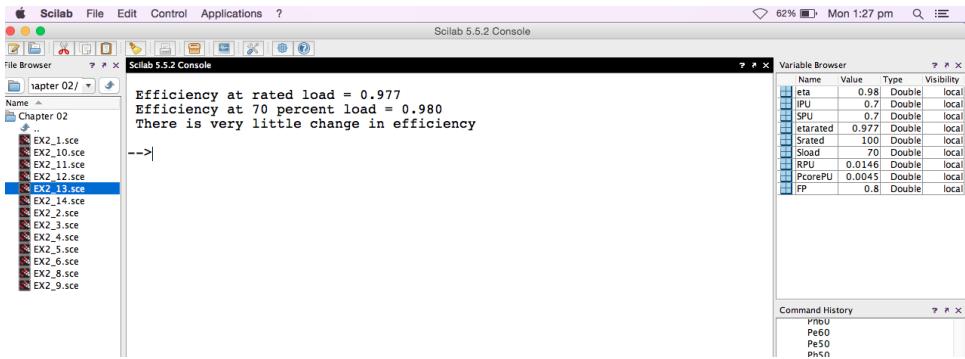


Figure 2.12: Determine Efficiency at rated load and 80 percent power factor and 70 percent load and 80 percent power factor

```

3 // (b) 70% load and 80% power factor
4 // Page No. 75
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 FP=0.80; // Power factor
12 PcorePU=0.0045; // Percentage core loss
13 RPU=0.0146; // Percentage resistance
14 Sload=70; // 70% rated load
15 Srated=100; // 100% rated load
16
17 // (a) Efficiency at rated load and 80% power factor
18 etarated=FP/(FP+RPU+PcorePU);
19
20 // (b) Efficiency at 70% load and 80% power factor
21 SPU=Sload/Srated;
22 IPU=SPU; // I_load
23 eta=(SPU*FP)/(SPU*FP+PcorePU+IPU^2*RPU) // Efficiency
24

```

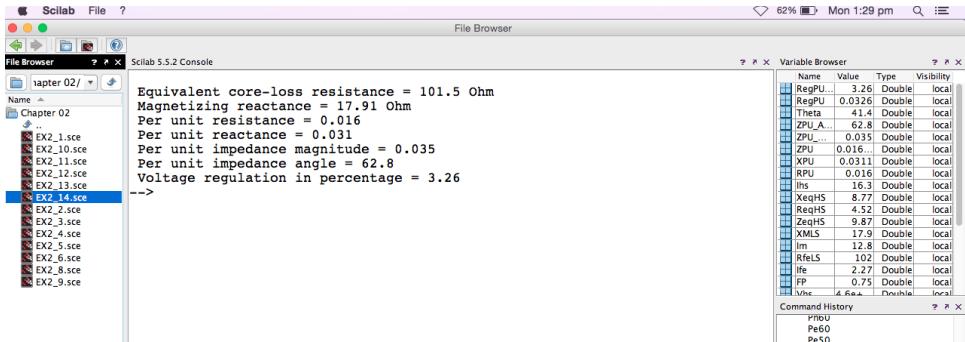


Figure 2.13: Determine Magnetizing reactance and equivalent core loss resistance and Per unit resistance reactance and impedance of transformer windings and Voltage regulation

```

25 // Display result on command window
26 printf("\n Efficiency at rated load = %0.3f ", 
        etarated);
27 printf("\n Efficiency at 70 percent load = %0.3f ", 
        eta);
28 disp('There is very little change in efficiency');

```

Scilab code Exa 2.14 Determine Magnetizing reactance and equivalent core loss resistance and Per unit resistance reactance and impedance of transformer windings and Voltage regulation

```

1 // Example 2.14
2 // Determine (a) Magnetizing reactance and
   equivalent core-loss resistance
3 // (b) Per unit resistance , reactance and impedance
   of transformer windings
4 // (c) Voltage regulation when operating at rated
   load and 0.75 power factor lagging
5 // Page No. 78

```

```

6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 Poc=521;                                // Open circuit test
13 power
14 Voc=230;                                // Open circuit voltage
15 Vo=230;                                 // Output voltage
16 Ioc=13.04;                               // Open circuit current
17 Vsc=160.8;                               // Short circuit voltage
18 Isc=16.3;                                // Short circuit current
19 Psc=1200;                                // Short circuit power
20 S=75000;                                 // Transformer rating
21 Vhs=4600;                                // High side voltage
22 FP=0.75;                                 // Power factor lagging
23
24 // (a) Magnetizing reactance and equivalent core-
25 // loss resistance
26 Ife=Poc/Voc;                            // Current rating
27 RfeLS=Vo/If e;                           // Core-loss resistance
28 Im=sqrt(Ioc^2-If e^2);                  // Magnetizing current
29 XMLS=Voc/Im;                            // Magnetizing reactance
30
31 // (b) Per unit resistance , reactance and impedance
32 // of transformer windings
33 ZeqHS=Vsc/Isc;                          // Equivalent impedance
34 ReqHS=Psc/Isc^2;                         // Equivalent resistance
35 XeqHS=sqrt(ZeqHS^2 - ReqHS^2);          // Equivalent
36 reactance
37 Ih s=S/Vhs;                            // High side current
38 RPU=Ihs*ReqHS/Vhs;                      // Per unit resistance
39 XPU=Ihs*XeqHS/Vhs;                      // Per unit reactance
40 ZPU=RPU+%i*XPU;                        // Per unit impedance
41
42 // Complex to Polar form...
43 ZPU_Mag=sqrt(real(ZPU)^2+imag(ZPU)^2); // Magnitude part

```

```

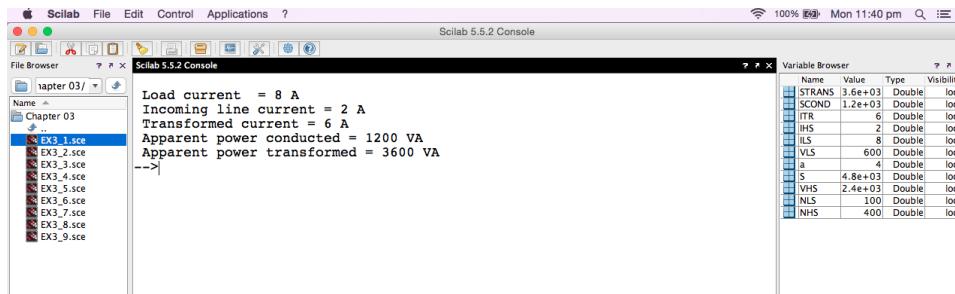
39 ZPU_Ang=atan(imag(ZPU),real(ZPU))*180/%pi; // Angle
      part
40
41 // (c) Voltage regulation when operating at rated
      load and 0.75 power factor lagging
42 // Transformer regulation
43 Theta=acosd(FP);
44 RegPU=sqrt( (RPU+FP)^2 + (XPU+sind(Theta))^2 )-1;
45 // Transformer regulation in percentage
46 RegPU_Per=RegPU*100;
47
48 // Display result on command window
49 printf("\n Equivalent core-loss resistance = %0.1f
      Ohm",RfeLS);
50 printf("\n Magnetizing reactance = %0.2f Ohm", XMLS)
      ;
51 printf("\n Per unit resistance = %0.3f ", RPU);
52 printf("\n Per unit reactance = %0.3f ", XPU);
53 printf("\n Per unit impedance magnitude = %0.3f ",
      ZPU_Mag);
54 printf("\n Per unit impedance angle = %0.1f ",
      ZPU_Ang);
55 printf("\n Voltage regulation in percentage = %0.2f
      ", RegPU_Per);

```

Chapter 3

Transformer Connections Operation and Specialty Transformers

Scilab code Exa 3.1 Computation of Load current and Incoming line current and Transformed current and Apparent power conducted and apparent power transformed



The screenshot shows the Scilab 5.5.2 interface. The console window displays the following output:

```
Load current = 8 A
Incoming line current = 2 A
Transformed current = 6 A
Apparent power conducted = 1200 VA
Apparent power transformed = 3600 VA
-->|
```

The variable browser window on the right lists the following variables:

Name	Value	Type	Visibility
STRANS	3.6e+03	Double	local
SOURCE	1.2e+03	Double	local
ITR	6	Double	local
IHS	2	Double	local
ILS	8	Double	local
VLS	600	Double	local
a	4	Double	local
S	4.8e+03	Double	local
VHS	2.4e+03	Double	local
NLS	100	Double	local
NHS	400	Double	local

Figure 3.1: Computation of Load current and Incoming line current and Transformed current and Apparent power conducted and apparent power transformed

```

1 // Example 3.1
2 // Computation of (a) Load current (b) Incoming line
   current
3 // (c) Transformed current (d) Apparent power
   conducted and apparent power transformed
4 // Page No. 98
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 NHS=400;           // Number of turns in the
                     high side
12 NLS=0.25*400;     // Number of turns in the low
                     side
13 VHS=2400;          // Voltage at the high side
14 S=4800;            // Supply voltage
15
16 // (a) Load current
17 a=NHS/NLS;         // Transformer turn ratio
18 VLS=VHS/a;         // Low side voltage
19 ILS=S/VLS;         // Load current
20
21 // (b) Incoming line current
22 IHS=ILS/a;
23
24 // (c) Transformed current
25 ITR=ILS-IHS;
26
27 // (d) Apparent power conducted and apparent power
   transformed
28
29 SCOND=IHS*VLS;     // Apparent power conducted
30 STRANS=ITR*VLS;    // Apparent power transformed
31
32
33 // Display result on command window

```

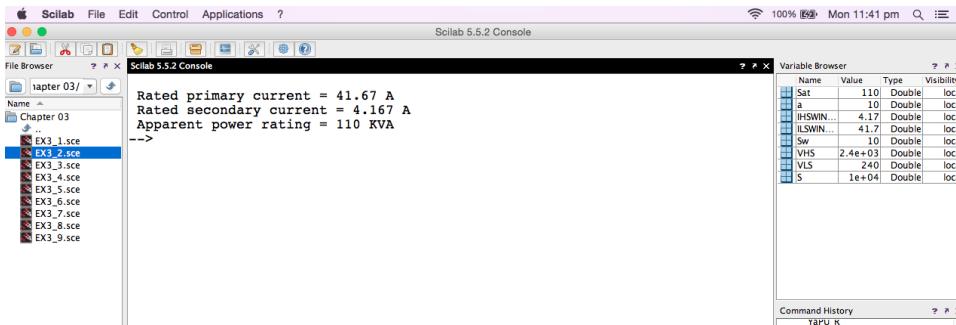


Figure 3.2: Computation of Rated primary and secondary currents and Apparent power rating

```

34 printf("\n Load current = %0.0f A ", ILS);
35 printf("\n Incoming line current = %0.0f A ", IHS);
36 printf("\n Transformed current = %0.0f A ", ITR);
37 printf("\n Apparent power conducted = %0.0f VA ",
       SCOND);
38 printf("\n Apparent power transformed = %0.0f VA ",
       STRANS);

```

Scilab code Exa 3.2 Computation of Rated primary and secondary currents and Apparent power rating

```

1 // Example 3.2
2 // Computation of (a) Rated primary and secondary
   currents when connected as
3 // autotransformer (b) Apparent power rating when
   connected as an autotransformer
4 // Page No. 100
5
6clc;
7clear;
8close;

```

```

9
10 // Given data
11 S=10000;           // Supply voltage
12 VLS=240;          // Voltage at the low side
13 VHS=2400;         // Voltage at the high side
14 Sw=10;            // Power rating
15
16 // (a) Rated primary and secondary currents when
   connected as autotransformer
17
18 ILSWINDING=S/VLS; // Rated primary current
19 IHSWINDING=S/VHS; // Rated secondary current
20
21
22 // (b) Apparent power rating when connected as an
   autotransformer
23
24 a=VHS/VLS;        // Magnetic drop across
   R1
25 Sat=(a+1)*Sw;
26
27
28 // Display result on command window
29
30 printf("\n Rated primary current = %0.2f A ", 
   ILSWINDING);
31 printf("\n Rated secondary current = %0.3f A ", 
   IHSWINDING);
32 printf("\n Apparent power rating = %0.0f KVA ",Sat);

```

Scilab code Exa 3.3 Computation of Buck boost transformer parameters and Repeating the same assuming utilization voltage as 246V

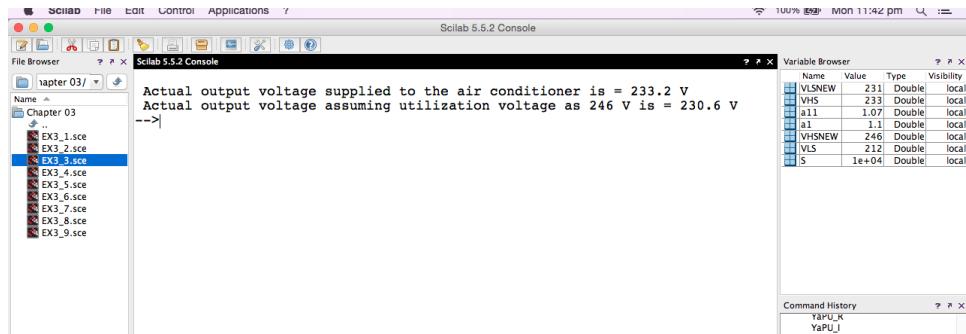


Figure 3.3: Computation of Buck boost transformer parameters and Repeating the same assuming utilization voltage as 246V

```

1 // Example 3.3
2 // Computation of (a) Buck boost transformer
   parameters
3 // (b) Repeating the same assuming utilization
   voltage as 246V
4 // Page No. 102
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 S=10000;           // Supply voltage
12 VLS=212;          // Voltage at the low side
13 VHSNEW=246;        // New voltage at the high
                     side
14 a1=1.100;
15 a11=1.0667;
16
17 // (a) Buck boost transformer parameters
18 VHS=a1*VLS;
19
20 // (b) Repeating the same assuming utilization
   voltage as 246V
21

```

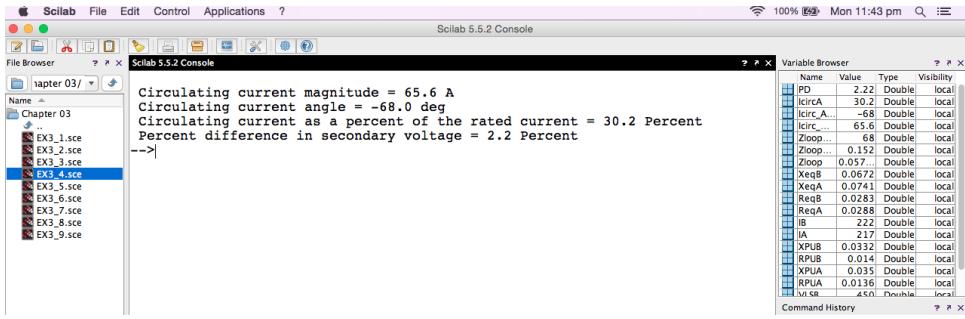


Figure 3.4: Determine Circulating current in the paralleled secondaries and Circulating current as a percent of the rated current of transformer A and Percent difference in secondary voltage

```

22 VLSNEW=VHSNEW/a11;
23
24 // Display result on command window
25
26 printf("\n Actual output voltage supplied to the air
           conditioner is = %0.1f V ",VHS);
27 printf("\n Actual output voltage assuming
           utilization voltage as 246 V is = %0.1f V ",
           VLSNEW);

```

Scilab code Exa 3.4 Determine Circulating current in the paralleled secondaries and Circulating current as a percent of the rated current of transformer A and Percent difference in secondary voltage

```

1 // Example 3.4
2 // Determine (a) Circulating current in the
   paralleled secondaries
3 // (b) Circulating current as a percent of the rated
   current of transformer A

```

```

4 // (c) Percent difference in secondary voltage that
   caused the circulating current
5 // Page No. 104
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 S=100000;                                // Transformer A and B rating
13 VLSA=460;                                 // Voltage at the low side of
                                              transformer A
14 VLSB=450;                                 // Voltage at the low side of
                                              transformer A
15 RPUA=0.0136;                             // Percent resistance of
                                              transformer A
16 XPUA=0.0350;                             // Percent reactance of
                                              transformer A
17 RPUB=0.0140;                             // Percent resistance of
                                              transformer B
18 XPUB=0.0332;                            // Percent reactance of
                                              transformer B
19
20
21
22 // (a) Circulating current in the paralleled
   secondaries
23 IA= S/VLSA;                             // Rated low side current
   for transformer A
24 IB= S/VLSB;                             // Rated low side current
   for transformer B
25 ReqA=RPUA*VLSA/IA;                     // Equivalent resistance
   of transfomer A
26 ReqB=RPUB*VLSB/IB;                      // Equivalent resistance
   of transfomer B
27 XeqA=XPUA*VLSA/IA;                     // Equivalent reactance of
   transfomer A
28 XeqB=XPUB*VLSB/IB;                      // Equivalent reactance of
                                              transformer B

```

```

        transfomer B
29
30 // Impedance of the closed loop formed by two
   secondaries is
31 Zloop=ReqA+%i*XeqA+ReqB+%i*XeqB;
32 // Complex to Polar form...
33 Zloop_Mag=sqrt(real(Zloop)^2+imag(Zloop)^2); // 
   Magnitude part
34 Zloop_Ang=atan(imag(Zloop),real(Zloop))*180/%pi; //
   Angle part
35
36 Icirc_Mag=(VLSA-VLSB)/Zloop_Mag; // Circulating
   current magnitude
37 Icirc_Ang=0- Zloop_Ang;           // Circulating
   current angle
38
39 // (b) Circulating current as a percent of the rated
   current of transformer A
40 IcircA=Icirc_Mag*100/IA;
41
42 // (c) Percent difference in secondary voltage that
   caused the circulating current
43 PD=(VLSA-VLSB)*100/VLSB;
44
45 // Display result on command window
46
47 printf("\n Circulating current magnitude = %0.1f A ",
   Icirc_Mag);
48 printf("\n Circulating current angle = %0.1f deg ",
   Icirc_Ang);
49 printf("\n Circulating current as a percent of the
   rated current = %0.1f Percent ",IcircA);
50 printf("\n Percent difference in secondary voltage =
   %0.1f Percent ",PD);

```

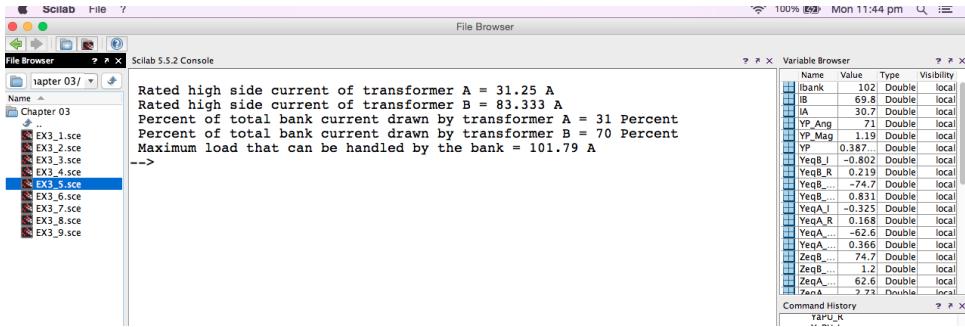


Figure 3.5: Determine Rated high side current of each transformer and Percent of the total bank current drawn by each transformer and Maximum load that can be handled by the bank without overloading by one of the transformer

Scilab code Exa 3.5 Determine Rated high side current of each transformer and Percent of the total bank current drawn by each transformer and Maximum load that can be handled by the bank without overloading by one of the transformer

```

1 // Example 3.5
2 // Determine (a) Rated high side current of each
   transformer (b) Percent of the
3 // total bank-current drawn by each transformer (c)
   Maximum load that can be
4 // handled by the bank without overloading by one of
   the transformer
5 // Page No. 107
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 SA=75000;           // Transformer A rating

```

```

13 SB=200000;           // Transformer B rating
14 VHSA=2400;           // Voltage at the high side
   of transformer A
15 VHSB=2400;           // Voltage at the high side
   of transformer B
16 RPUA=1.64;           // Percent resistance of
   transformer A
17 XPUA=3.16;           // Percent reactance of
   transformer A
18 RPUB=1.10;           // Percent resistance of
   transformer B
19 XPUB=4.03;           // Percent reactance of
   transformer B
20
21
22
23 // (a) Rated high side current of each transformer
24 IArated=SA/VHSA;      // High side rated current
   transformer A
25 IBrated=SB/VHSB;      // High side rated current
   transformer B
26
27 // (b) Percent of the total bank-current drawn by
   each transformer
28 ZAper=RPUA+%i*XPUA;    // Percent impadance for
   transformer A
29 // Complex to Polar form...
30 ZAper_Mag=sqrt(real(ZAper)^2+imag(ZAper)^2);      //
   Magnitude part
31 ZAper_Ang=atan(imag(ZAper),real(ZAper))*180/%pi;   //
   Angle part
32
33 ZBper=RPUB+%i*XPUB;    // Percent impadance for
   transformer B
34 // Complex to Polar form...
35 ZBper_Mag=sqrt(real(ZBper)^2+imag(ZBper)^2);      //
   Magnitude part
36 ZBper_Ang=atan(imag(ZBper),real(ZBper))*180/%pi;   //

```

```

        Angle part

37
38 ZAbase=VHSA/IArated;                                // Base
            impedance of transformer A
39 ZBbase=VHSB/IBrated;                                // Base
            impedance of transformer A
40
41 ZeqA_Mag=ZAbase*Zaper_Mag/100;                      // Magnitude of
            equivalent impedance A
42 ZeqA_Ang=Zaper_Ang;                                  // Angle of
            equivalent impedance A
43
44 ZeqB_Mag=ZBbase*ZBper_Mag/100;                      // Magnitude of
            equivalent impedance B
45 ZeqB_Ang=ZBper_Ang;                                  // Angle of
            equivalent impedance B
46
47 YeqA_Mag=1/ZeqA_Mag;                                // Magnitude of
            equivalent admittance A
48 YeqA_Ang=0-ZeqA_Ang;                                // Angle of
            equivalent admittance A
49
50 // Polar to Complex form
51 YeqA_R=YeqA_Mag*cos(-YeqA_Ang*pi/180); // Real part
            of complex number
52 YeqA_I=YeqA_Mag*sin(YeqA_Ang*pi/180); //Imaginary
            part of complex number
53
54 YeqB_Mag=1/ZeqB_Mag;                                // Magnitude of
            equivalent admittance B
55 YeqB_Ang=0-ZeqB_Ang;                                // Angle of
            equivalent admittance B
56
57 // Polar to Complex form
58
59 YeqB_R=YeqB_Mag*cos(-YeqB_Ang*pi/180); // Real part
            of complex number
60 YeqB_I=YeqB_Mag*sin(YeqB_Ang*pi/180); //Imaginary

```

```

        part of complex number
61 YP=(YeqA_R - %i* YeqA_I)+(YeqB_R - %i* YeqB_I); // 
    Parallel admittance
62
63 // Complex to Polar form...
64 YP_Mag=sqrt(real(YP)^2+imag(YP)^2); // 
    Magnitude part
65 YP_Ang=atan(imag(YP),real(YP))*180/%pi; // Angle
    part
66
67 IA=YeqA_Mag/YP_Mag; // 
    Transformer A load
68 IB=YeqB_Mag/YP_Mag; // 
    Transformer A load
69 IA=IA*100;
70 IB=IB*100;
71
72 // (c) Maximum load that can be handled by the bank
    without overloading by
73 // one of the transformer
74 Ibank=IArated/0.307;
75
76 // Display result on command window
77
78 printf("\n Rated high side current of transformer A
    = %0.2f A ",IArated);
79 printf("\n Rated high side current of transformer B
    = %0.3f A ",IBrated);
80 printf("\n Percent of total bank current drawn by
    transformer A = %0.0f Percent ",IA);
81 printf("\n Percent of total bank current drawn by
    transformer B = %0.0f Percent ",IB);
82 printf("\n Maximum load that can be handled by the
    bank = %0.2f A ", Ibank);

```

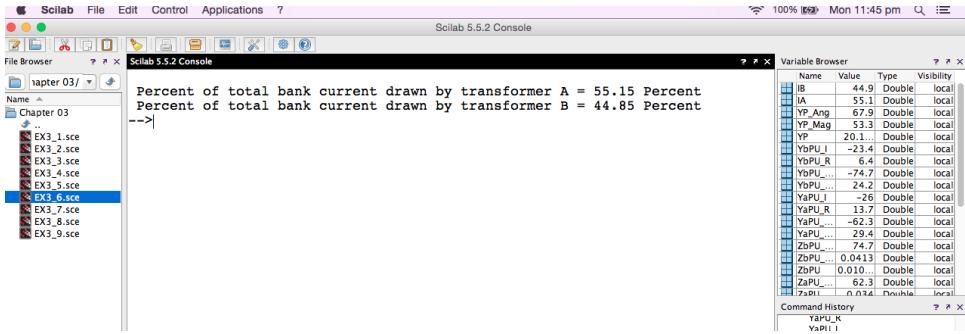


Figure 3.6: Determine the percent of the total bank current drawn by each transformer

Scilab code Exa 3.6 Determine the percent of the total bank current drawn by each transformer

```

1 // Example 3.6
2 // Determine the percent of the total bank-current
   drawn by each transformer
3 // Page No. 109
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 ZaPU_R=0.0158;           // Transformer A impedance
   real part
11 ZaPU_I=0.0301;           // Transformer A impedance
   imaginary part
12 ZbPU_R=0.0109;           // Transformer B impedance
   real part
13 ZbPU_I=0.0398;           // Transformer B impedance
   imaginary part
14 SB=200000;               // Transformer B rating

```

```

15 VHSa=2400; // Voltage at the high side
   of transformer A
16 VHsB=2400; // Voltage at the high side
   of transformer B
17 RPua=1.64; // Percent resistance of
   transformer A
18 XpuA=3.16; // Percent reactance of
   transformer A
19 RPub=1.10; // Percent resistance of
   transformer B
20 Xpub=4.03; // Percent reactance of
   transformer B
21
22
23
24 // Base impedance of transformer A
25 ZaPU=ZaPU_R+%i*ZaPU_I;
26 // Complex to Polar form...
27 ZaPU_Mag=sqrt(real(ZaPU)^2+imag(ZaPU)^2); // // Magnitude part
28 ZaPU_Ang=atan(imag(ZaPU),real(ZaPU))*180/%pi; // // Angle part
29
30 // Base impedance of transformer B
31 ZbPU=ZbPU_R+%i*ZbPU_I;
32 // Complex to Polar form...
33 ZbPU_Mag=sqrt(real(ZbPU)^2+imag(ZbPU)^2); // // Magnitude part
34 ZbPU_Ang=atan(imag(ZbPU),real(ZbPU))*180/%pi; // // Angle part
35
36 // Admittance of transformer A
37 YaPU_Mag=1/ZaPU_Mag; // Magnitude of
   equivalent admittance A
38 YaPU_Ang=0-ZaPU_Ang; // Angle of
   equivalent admittance A
39
40 // Polar to Complex form

```

```

41
42 YaPU_R=YaPU_Mag*cos(-YaPU_Ang*pi/180); // Real part
   of complex number
43 YaPU_I=YaPU_Mag*sin(YaPU_Ang*pi/180); //Imaginary
   part of complex number
44
45 // Admittance of transformer B
46 YbPU_Mag=1/ZbPU_Mag;                      // Magnitude of
   equivalent admittance B
47 YbPU_Ang=0-ZbPU_Ang;                      // Angle of
   equivalent admittance B
48 // Polar to Complex form
49
50 YbPU_R=YbPU_Mag*cos(-YbPU_Ang*pi/180); // Real part
   of complex number
51 YbPU_I=YbPU_Mag*sin(YbPU_Ang*pi/180); //Imaginary
   part of complex number
52
53 // Parallel admittance
54 YP=(YaPU_R-%i*YaPU_I)+(YbPU_R-%i*YbPU_I);
55 // Complex to Polar form...
56 YP_Mag=sqrt(real(YP)^2+imag(YP)^2);        //
   Magnitude part
57 YP_Ang=atan(imag(YP),real(YP))*180/pi;    // Angle
   part
58
59 IA=YaPU_Mag/YP_Mag*100;                     // Percent
   current drawn by transformer A
60 IB=100-IA;
61
62 // Display the result on the command window
63 printf("\n Percent of total bank current drawn by
   transformer A = %0.2f Percent ",IA);
64 printf("\n Percent of total bank current drawn by
   transformer B = %0.2f Percent ",IB);

```

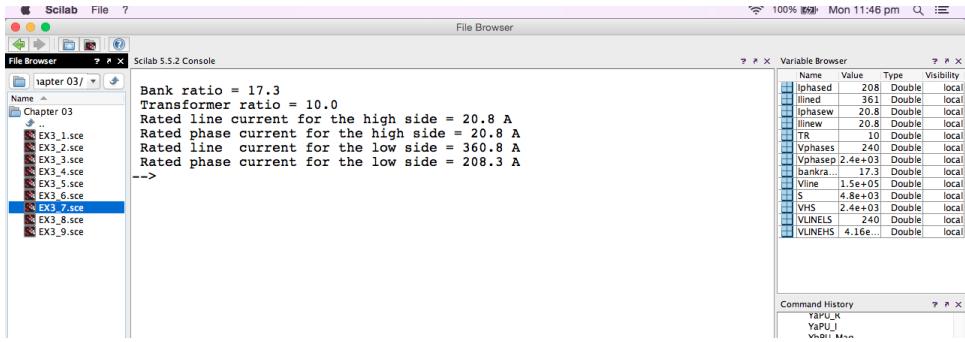


Figure 3.7: Computation of Bank ratio and Transformer ratio and Rated line and phase currents for the high side and Rated line and phase currents for the low side

Scilab code Exa 3.7 Computation of Bank ratio and Transformer ratio and Rated line and phase currents for the high side and Rated line and phase currents for the low side

```

1 // Example 3.7
2 // Computation of (a) Bank ratio (b) Transformer
   ratio (c) Rated line and phase
3 // currents for the high side (d) Rated line and
   phase currents for the low side
4 // Page No. 113
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 VLINEHS=4160; // Number of turns in
   the high side
12 VLINELS=240; // Number of turns in

```

```

          the low side
13 VHS=2400;                      // Voltage at the high
           side
14 S=4800;                         // Supply voltage
15 Vline=150000;                   // Transformer rating
16
17 // (a) Bank ratio
18 bankratio=VLINELHS/VLINEELS;
19
20 // (b) Transformer ratio
21 Vphasep= VLINEHS/ sqrt(3);      // For wye primary
22 Vphases=VLINEELS                // For secondary
23 TR=Vphasep/Vphases;             // Transformer ratio
24
25 // (c) Rated line and phase currents for the high
           side
26 Ilinew=Vline/(sqrt(3)*VLINELHS);
27 Iphasew=Ilinew;
28
29 // (d) Rated line and phase currents for the low
           side
30 Ilined=Vline/(sqrt(3)*VLINELHS);
31 Iphased=Ilined/sqrt(3);
32
33
34 // Display result on command window
35 printf("\n Bank ratio = %0.1f ",bankratio);
36 printf("\n Transformer ratio = %0.1f ",TR);
37 printf("\n Rated line current for the high side = %0
           .1f A ",Ilinew);
38 printf("\n Rated phase current for the high side =
           %0.1f A ",Iphasew);
39 printf("\n Rated line current for the low side = %0
           .1f A ",Ilined);
40 printf("\n Rated phase current for the low side = %0
           .1f A ",Iphased);

```

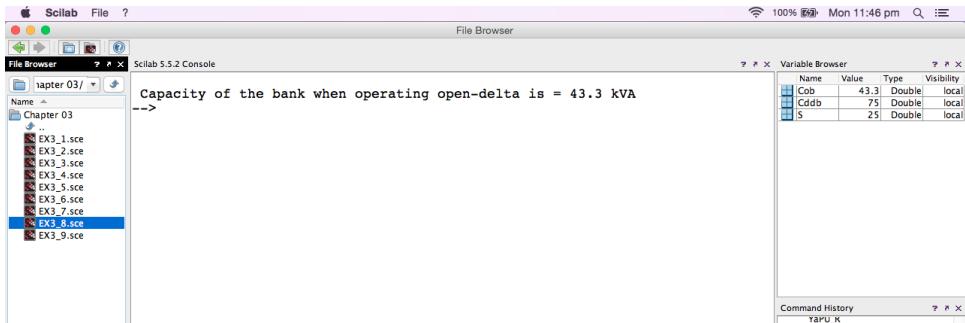


Figure 3.8: Determine the maximum allowable power that the open delta bank handle without overheating

Scilab code Exa 3.8 Determine the maximum allowable power that the open delta bank handle without overheating

```

1 // Example 3.8
2 // Determine the maximum allowable power that the
   open-delta bank handle
3 // without overheating
4 // Page No. 117
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 S=25;                                // Transformer rating
12
13 // Capacity of the delta-delta bank is
14 Cddb=S*3;
15 // Capacity of the bank when operating open-delta is
16 Cob=Cddb*0.577;
```

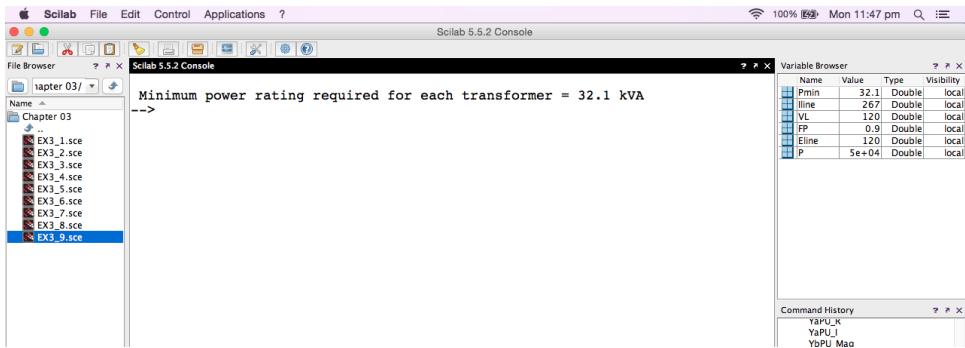


Figure 3.9: Determine the minimum power rating required for each transformer

```

17
18
19 // Display result on command window
20 printf("\n Capacity of the bank when operating open-
delta is = %0.1f kVA ", Cob);

```

Scilab code Exa 3.9 Determine the minimum power rating required for each transformer

```

1 // Example 3.9
2 // Determine the minimum power rating required for
   each transformer
3 // Page No. 117
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 P=50000; // Transformer power

```

```

    rating
11 Eline=120;                      // Line voltage
12 FP=0.9                           // Power factor
    lagging
13 VL=120;
14
15 // Line current is
16 Iline=P/(sqrt(3)*Eline*FP);
17
18 // Minimum power rating required for each
    transformer
19 Pmin=VL*Iline/1000;
20
21
22 // Display result on command window
23 printf("\n Minimum power rating required for each
    transformer = %0.1f kVA ",Pmin);

```

Chapter 4

Principles of Three Phase Induction Motors

Scilab code Exa 4.1 Computation of synchronous speed of a six pole induction motor

```
1 // Example 4.1
2 // Computation of synchronous speed of a six pole
   induction motor
3 // Page No. 140
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 f=60;           // Frequency
11 p=6;            // Number of poles
12
13
14 fs=f*0.85;     // Frequency is 85% of its
   rated value
```

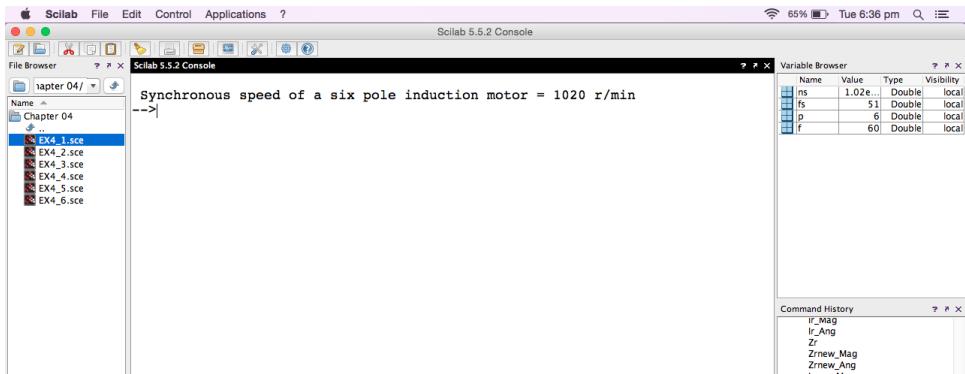


Figure 4.1: Computation of synchronous speed of a six pole induction motor

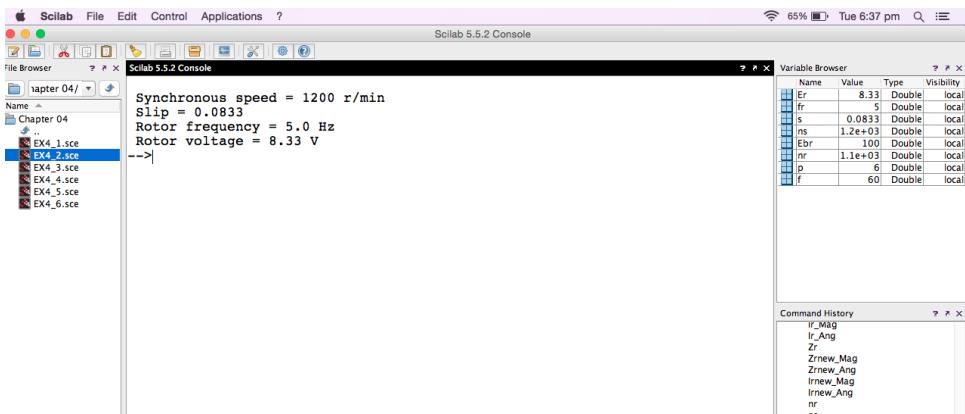


Figure 4.2: Computation of Frequency and Induced voltage of six pole induction motor

```

15 ns=120*fs/p;           // Synchronous speed
16
17 // Display result on command window
18 printf("\n Synchronous speed of a six pole induction
motor = %0.0 f r/min ",ns);

```

Scilab code Exa 4.2 Computation of Frequency and Induced voltage of six pole induction motor

```
1 // Example 4.2
2 // Computation of (a) Frequency (b) Induced voltage
   // of six pole induction motor
3 // Page No. 143
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 f=60;           // Frequency
11 p=6;            // Number of poles
12 nr=1100;        // Rotor speed
13 Ebr=100;        // Blocked rotor voltage
14
15 // (a) Synchronous speed
16 ns=120*f/p;    // Synchronous speed
17
18 // (b) Slip
19 s=(ns-nr)/ns;  // Slip
20
21 // (c) Rotor frequency
22 fr=s*f;         // Rotor frequency
23
24 // (d) Rotor voltage
25 Er=s*Ebr;       // Rotor voltage
26
27
28 // Display result on command window
29 printf("\n Synchronous speed = %0.0f r/min ",ns);
30 printf("\n Slip = %0.4f ",s);
31 printf("\n Rotor frequency = %0.1f Hz ",fr);
32 printf("\n Rotor voltage = %0.2f V ",Er);
```

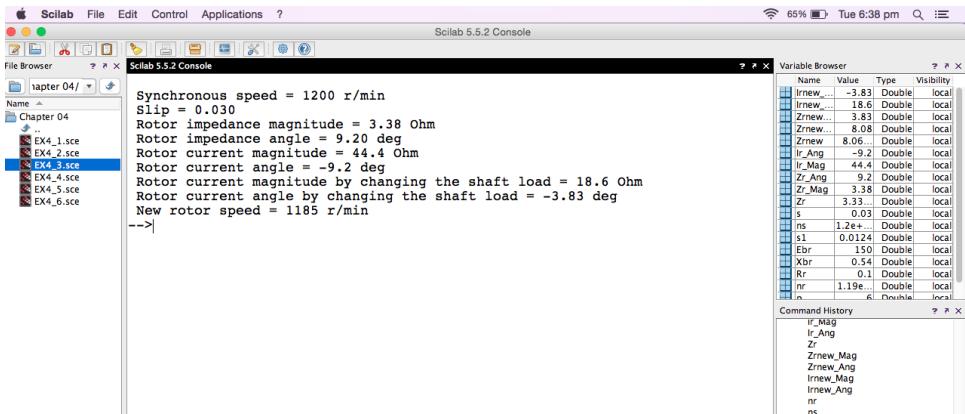


Figure 4.3: Determine Synchronous speed and Slip and Rotor impedance and Rotor current and Rotor current by changing the shaft load and Speed

Scilab code Exa 4.3 Determine Synchronous speed and Slip and Rotor impedance and Rotor current and Rotor current by changing the shaft load and Speed

```

1 // Example 4.3
2 // Determine (a) Synchronous speed (b) Slip (c)
   Rotor impedance (d) Rotor current
3 // (e) Rotor current if changing the shaft load
   resulted in 1.24 percenr slip
4 // (f) Speed for the condition in (e)
5 // Page No. 146
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 fs=60; // Frequency

```

```

13 p=6;                                // Number of poles
14 nr=1164;                            // Rotor speed
15 Rr=0.10;                            // Equivalent resistance
16 Xbr=0.54;                            // Equivalent reactance
17 Ebr=150;                             // Blocked rotor voltage per
                                         phase
18 s1=0.0124;                          // Percent slip
19
20 // (a) Synchronous speed
21 ns=120*fS/p;                        // Speed
22
23 // (b) Slip
24 s=(ns-nr)/ns;
25
26 // (c) Rotor impedance
27 Zr=(Rr/s)+%i*Xbr;
28 // Complex to Polar form...
29 Zr_Mag=sqrt(real(Zr)^2+imag(Zr)^2); // Magnitude part
30 Zr_Ang=atan(imag(Zr),real(Zr))*180/%pi; // Angle part
31
32 // (d) Rotor current
33 Ir_Mag=Ebr/Zr_Mag;                  // Magnitude
34 Ir_Ang=0-Zr_Ang;                   // Angle
35
36 // (e) Rotor current if changing the shaft load
                                         resulted in 1.24 percent slip
37 Zrnew=Rr/s1+%i*Xbr;
38 // Complex to Polar form...
39 Zrnew_Mag=sqrt(real(Zrnew)^2+imag(Zrnew)^2); // Magnitude part
40 Zrnew_Ang=atan(imag(Zrnew),real(Zrnew))*180/%pi; // Angle part
41
42 Irnew_Mag=Ebr/Zrnew_Mag;           // Magnitude

```

```

43 Irnew_Ang=0-Zrnew_Ang; // Angle
44
45 // (f) Speed for the condition in (e)
46 nr=ns*(1-s1);
47
48 // Display result on command window
49 printf("\n Synchronous speed = %0.0f r/min ",ns);
50 printf("\n Slip = %0.3f ",s);
51 printf("\n Rotor impedance magnitude = %0.2f Ohm ",Zr_Mag);
52 printf("\n Rotor impedance angle = %0.2f deg ",Zr_Ang);
53 printf("\n Rotor current magnitude = %0.1f Ohm ",Ir_Mag);
54 printf("\n Rotor current angle = %0.1f deg ",Ir_Ang);
55 ;
55 printf("\n Rotor current magnitude by changing the
      shaft load = %0.1f Ohm ",Irnew_Mag);
56 printf("\n Rotor current angle by changing the shaft
      load = %0.2f deg ",Irnew_Ang);
57 printf("\n New rotor speed = %0.0f r/min ",nr);

```

Scilab code Exa 4.4 Determine Total three phase apparent power crossing the air gap and Active and reactive components and Rotor power factor

```

1 // Example 4.4
2 // Determine (a) Total three phase apparent power
   crossing the air gap
3 // (b) Active and reactive components (c) Rotor
   power factor
4 // Page No. 149
5

```

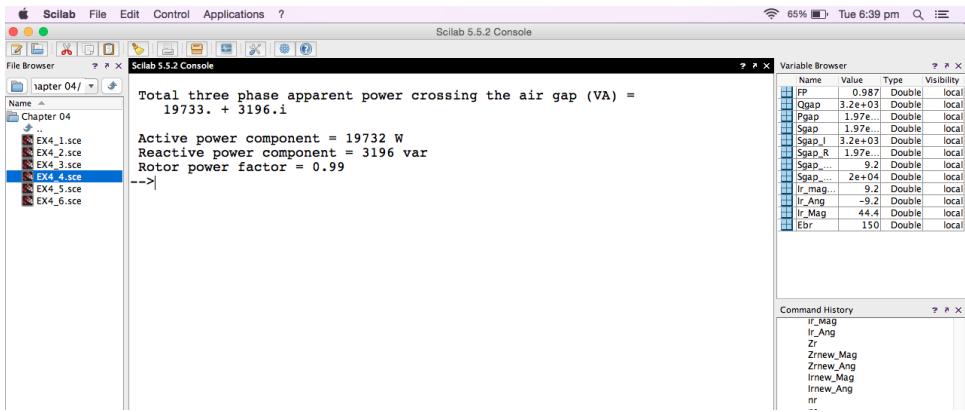


Figure 4.4: Determine Total three phase apparent power crossing the air gap and Active and reactive components and Rotor power factor

```

6 clc;
7 clear;
8 close;
9
10 // Given data
11 Ebr=150; // Blocked rotor voltage per
           // phase
12 Ir_Mag=44.421; // Rotor current magnitude
13 Ir_Ang=-9.2; // Rotor current angle
14 Ir_magConj=9.2;
15
16
17 // (a) Total three phase apparent power crossing the
      // air gap
18 Sgap_Mag=3*Ebr*Ir_Mag; // Apparent power
      // crossing the air gap magnitude
19 Sgap_Ang=Ir_magConj; // Apparent power
      // crossing the air gap angle
20
21 // Polar to Complex form
22 Sgap_R=Sgap_Mag*cos(-Sgap_Ang*pi/180); // Real part
      // of complex number
23 Sgap_I=Sgap_Mag*sin(Sgap_Ang*pi/180); // Imaginary

```

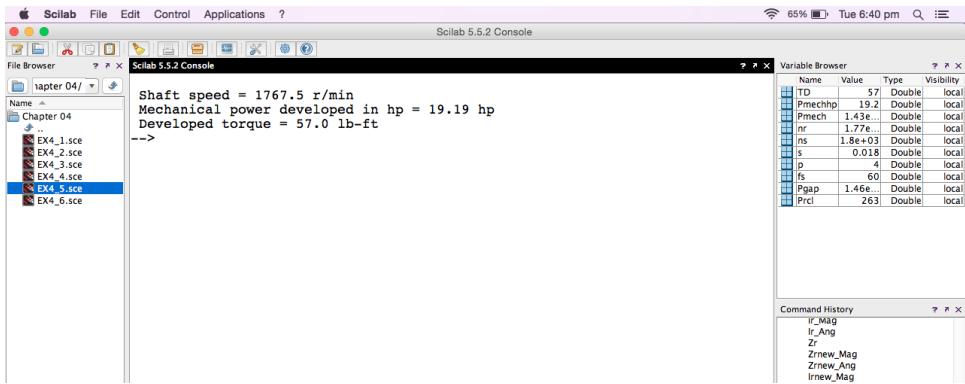


Figure 4.5: Computation of Shaft speed and Mechanical power developed and Developed torque

```

        part of complex number
24 Sgap=ceil(Sgap_R)+%i*ceil(Sgap_I);
25
26 // (b) Active and reactive components
27 Pgap=Sgap_R;                                // Active power component
28 Qgap=Sgap_I;                                // Reactive power
                                               component
29
30 // (c) Rotor power factor
31 FP=cosd(Ir_magConj);
32
33 // Display result on command window
34 printf("\n Total three phase apparent power crossing
       the air gap (VA) =");
35 disp(Sgap);
36 printf("\n Active power component = %0.0 f W",Pgap);
37 printf("\n Reactive power component = %0.0 f var",
       Qgap);
38 printf("\n Rotor power factor = %0.2 f ",FP);

```

Scilab code Exa 4.5 Computation of Shaft speed and Mechanical power developed and Developed torque

```
1 // Example 4.5
2 // Computation of (a) Shaft speed (b) Mechanical
   power developed
3 // (c) Developed torque
4 // Page No. 152
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 Prcl=263;                      // Rotor copper loss
12 Pgap=14580;                    // Power input to the rotor
13 fs=60;                         // Frequency
14 p=4;                           // Number of poles
15
16
17
18 // (a) Shaft speed
19 s=Prcl/Pgap;                   // Slip
20 ns=120*fs/p;                  // Speed of stator
21 nr=ns*(1-s);                 // Speed of shaft
22
23 // (b) Mechanical power developed
24 Pmech=Pgap-Prcl;              // Mechanical
   power developed
25 Pmechhp=Pmech/746;            // Mechanical
   power developed in hp
26
27 // (c) Developed torque
28 TD=5252*Pmechhp/nr;
29
30
31 // Display result on command window
32 printf("\n Shaft speed = %0.1f r/min ",nr);
```

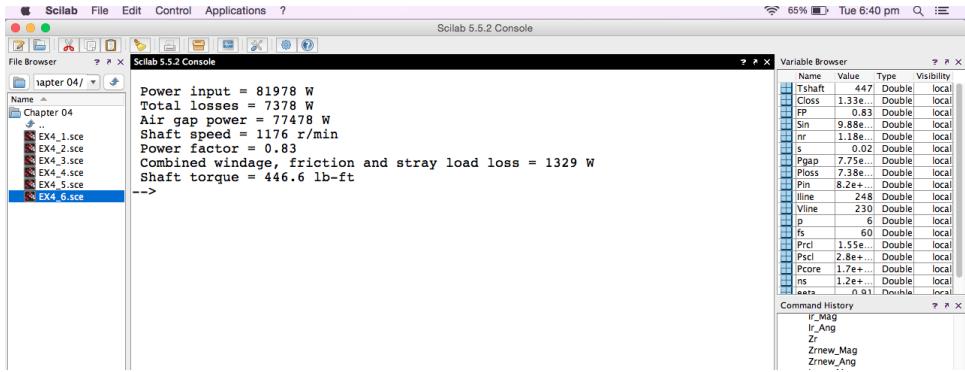


Figure 4.6: Determine Power input and Total losses and Air gap power and Shaft speed and Power factor and Combined windage friction and stray load loss and Shaft torque

```

33 printf("\n Mechanical power developed in hp = %0.2f
      hp ",Pmechhp);
34 printf("\n Developed torque = %0.1f lb-ft ",TD);

```

Scilab code Exa 4.6 Determine Power input and Total losses and Air gap power and Shaft speed and Power factor and Combined windage friction and stray load loss and Shaft torque

```

1 // Example 4.6
2 // Determine (a) Power input (b) Total losses (c)
   Air gap power (d) Shaft speed
3 // (e) Power factor (f) Combined windage , friction
   and stray load loss
4 // (g) Shaft torque
5 // Page No. 159
6
7 clc;
8 clear;
9 close;

```

```

10
11 // Given data
12 Pshaft=74600; // Shaft power
13 eeta=0.910; // Rated efficiency
14 ns=1200; // Speed of stator
15 Pcore=1697; // Power in core
16 Pscl=2803; // Stator copper loss
17 Prcl=1549; // Rotor copper loss
18 fs=60; // Synchronous
    frequency
19 p=6; // Number of poles
20 Vline=230; // Line voltage
21 Iline=248; // Line current
22
23 // (a) Power input
24 Pin=Pshaft/eeta; // Parallel resistance
25
26 // (b) Total losses
27 Ploss=Pin-Pshaft;
28
29 // (c) Air gap power
30 Pgap=Pin-Pcore-Pscl;
31
32 // (d) Shaft speed
33 s=Prcl/Pgap; // Parallel resistance
34 ns=120*fs/p;
35 nr=ns*(1-s);
36
37 // (e) Power factor
38 Sin=sqrt(3)*Vline*Iline;
39 FP=Pin/Sin;
40
41 // (f) Combined windage, friction and stray load loss
42 Closs=Ploss-Pcore-Pscl-Prcl;
43
44 // (g) Shaft torque
45 Tshaft=5252*100/nr;
46

```

```
47
48 // Display result on command window
49 printf("\n Power input = %0.0f W",Pin);
50 printf("\n Total losses = %0.0f W",Ploss);
51 printf("\n Air gap power = %0.0f W ",Pgap);
52 printf("\n Shaft speed = %0.0f r/min ",nr);
53 printf("\n Power factor = %0.2f ",FP);
54 printf("\n Combined windage , friction and stray load
      loss = %0.0f W ",Closs);
55 printf("\n Shaft torque = %0.1f lb-ft ",Tshaft);
```

Chapter 5

Classification Performance Applications and Operation of Three Phase Induction Machines

Scilab code Exa 5.1 Computation of minimum value of Locked rotor torque and Breakdown torque and Pull up torque

```
1 // Example 5.1
2 // Computation of minimum value of (a) Locked rotor
   torque (b) Breakdown torque
3 // (c) Pull up torque
4 // Page No. 173
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 f=60;           // Frequency in Hz
```

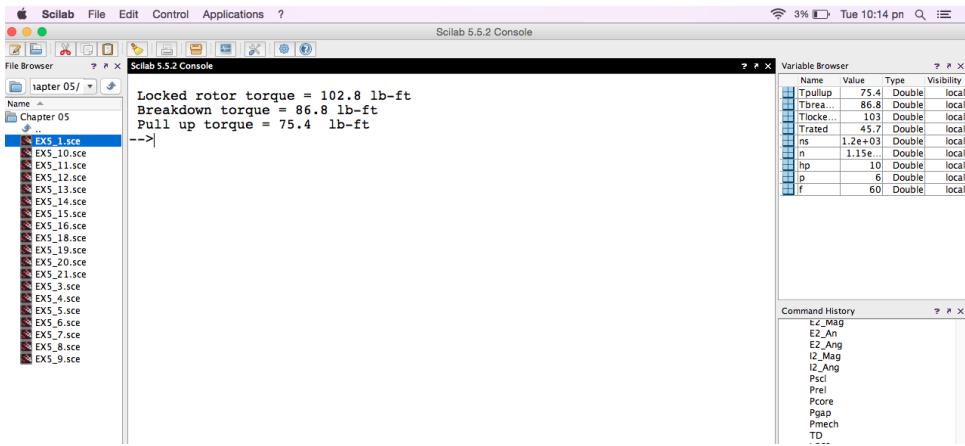


Figure 5.1: Computation of minimum value of Locked rotor torque and Breakdown torque and Pull up torque

```

12 p=6; // Number of poles
13 hp=10; // Horsepower
14 n=1150; // Rated speed of machine
15 ns=120*f/p;
16
17
18 // (a) Locked rotor torque
19 Trated=hp*5252/n; // Rated torque
20 Tlockedrotor=2.25*Trated;
21
22 // (b) Breakdown torque
23 Tbreakdown=1.90*Trated;
24
25 // (c) Pull up torque
26 Tpullup=1.65*Trated;
27
28
29 // Display result on command window
30 printf("\n Locked rotor torque = %0.1f lb-ft ", Tlockedrotor);
31 printf("\n Breakdown torque = %0.1f lb-ft ", Tbreakdown);

```

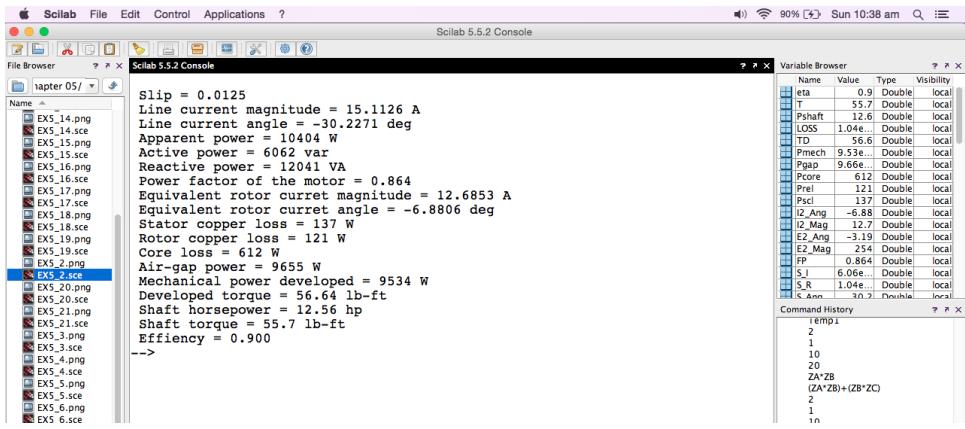


Figure 5.2: Determine Slip and Line current and Apparent power active power reactive power and power factor of the motor and Equivalent rotor current and Stator copper loss and Rotor copper loss and Core loss and Air gap power and Mechanical power developed

```
32 printf("\n Pull up torque = %0.1f lb-ft", Tpullup);
```

Scilab code Exa 5.2 Determine Slip and Line current and Apparent power active power reactive power and power factor of the motor and Equivalent rotor current and Stator copper loss and Rotor copper loss and Core loss and Air gap power and Mechanical power developed

```

1 // Example 5.2
2 // Determine (a) Slip (b) Line current (c) Apparent
   power, active power,
3 // reactive power and power factor of the motor (d)
   Equivalent rotor current
4 // (e) Stator copper loss (f) Rotor copper loss (g)
   Core loss (h) Air-gap
5 // power (i) Mechanical power developed (j)
   Developed torque (k) Shaft
```

```

6 // horsepower (l) Shaft torque (m) Effiency
7 // Page No. 180
8
9 clc;
10 clear;
11 close;
12
13 // Given data
14 f=60; // Frequency
15 P=6; // Number of poles
16 nr=1185;
17 R1=0.200; // Motor resistance
18 R2=0.250;
19 X1=1.20; // Motor reactance
20 X2=1.29;
21 Rfe=317; // Field resistance
22 XM=42; // Motor reactance
23 V=460; // Voltage rating
24 PFPS=166; // Stray loss
25
26 // (a) Slip
27 ns=(120*f)/P;
28 s=(ns-nr)/ns; // Speed difference
29
30 // (b) Line current
31 Z2=(R2/s)+%i*X2;
32 // Complex to Polar form...
33 Z2_Mag=sqrt(real(Z2)^2+imag(Z2)^2); // Magnitude part
34 Z2_Ang = atan(imag(Z2),real(Z2))*180/%pi; // Angle part
35
36 Z0_Num_Mag=Rfe*XM; // Z0 numerator
37 Z0_Num_Ang=0+90;
38
39 Z0_Den_R=Rfe; // Z0 denominator
40 Z0_Den_I=XM;
41 Z0_Den=Z0_Den_R+%i*Z0_Den_I;

```

```

42 // Complex to Polar form...
43 Z0_Den_Mag=sqrt(real(Z0_Den)^2+imag(Z0_Den)^2);
    // Magnitude part
44 Z0_Den_Ang = atan(imag(Z0_Den),real(Z0_Den))*180/%pi
    ; // Angle part
45
46 Z0_Mag=Z0_Num_Mag/Z0_Den_Mag;                      //
    Magnitude of Z0
47 Z0_Ang=Z0_Num_Ang-Z0_Den_Ang;                      //
    Z0
48
49 // Polar to Complex form
50 Z0_R=Z0_Mag*cos(-Z0_Ang*%pi/180);                //
    Real part
    of complex number
51 Z0_I=Z0_Mag*sin(Z0_Ang*%pi/180);                  //
    Imaginary
    part of complex number
52
53 // ZP computation
54 ZP_Nom_Mag=Z2_Mag*Z0_Mag;                          //
    numerator magnitude
55 ZP_Nom_Ang=Z2_Ang+Z0_Ang;                          //
    numerator angle
56
57 ZP_Den_R=real(Z2)+Z0_R;                            //
    Real part
    of ZP denominator
58 ZP_Den_I=imag(Z2)+Z0_I;
59 ZP_Den=ZP_Den_R+%i*ZP_Den_I;                     //
    ZP in
    complex form
60
61 // Complex to Polar form...
62 ZP_Den_Mag=sqrt(real(ZP_Den)^2+imag(ZP_Den)^2);
    // Magnitude part
63 ZP_Den_Ang = atan(imag(ZP_Den),real(ZP_Den))*180/%pi
    ; // Angle part
64
65 ZP_Mag=ZP_Nom_Mag/ZP_Den_Mag;                     //
    vlaue of ZP in polar form
66 ZP_Ang=ZP_Nom_Ang-ZP_Den_Ang;

```

```

67 // Polar to Complex form
68 ZP_R=ZP_Mag*cos(-ZP_Ang*%pi/180);           // Real part
       of complex number
69 ZP_I=ZP_Mag*sin(ZP_Ang*%pi/180);           // Imaginary
       part of complex number
70
71 // Zin computation
72 ZP=ZP_R+%i*ZP_I;                           // Parallel
       impedance
73 Z1=R1+%i*X1;                             // Input
       impedance
75 // Complex to Polar form ...
76 Zin_Mag=sqrt(real(Zin)^2+imag(Zin)^2);      // Magnitude part
77 Zin_Ang = atan(imag(Zin),real(Zin))*180/%pi; // Angle part
78
79 // I1 computation
80 I1_Mag=(V/sqrt(3))/Zin_Mag;                 // I1
       magnitude
81 I1_Ang=0-Zin_Ang;                          // I1 angle
82
83 // (c) Apparent power, active power, reactive power
       and power factor of the motor
84 S_Mag=3*(V/sqrt(3))*I1_Mag;                 // S magnitude
85 S_Ang=0-(-Zin_Ang);                        // S angle
86
87 // Polar to Complex form
88 S_R=S_Mag*cos(-S_Ang*%pi/180);            // Real part of
       complex number
89 S_I=S_Mag*sin(S_Ang*%pi/180);             // Imaginary
       part of complex number
90
91 FP=cosd(S_Ang);                          // Power factor
92
93 // (d) Equivalent rotor current
94 E2_Mag=I1_Mag*ZP_Mag;                     // E2 magnitude

```

```

95 E2_Ang=I1_Ang+ZP_Ang; // E2 angle
96
97 I2_Mag=E2_Mag/Z2_Mag; // I2 magnitude
98 I2_Ang=E2_Ang-Z2_Ang; // I2 angle
99
100 // (e) Stator copper loss
101 Pscl=3*I1_Mag^2*R1;
102
103 // (f) Rotor copper loss
104 Prel=3*I2_Mag^2*R2;
105
106 // (g) Core loss
107 Pcore=3*(E2_Mag^2/Rfe);
108
109 // (h) Air-gap power
110 Pgap=Prel/s;
111
112 // (i) Mechanical power developed
113 Pmech=Prel*(1-s)/s;
114
115 // (j) Developed torque
116 TD=(21.12*I2_Mag^2*R2)/(s*ns);
117
118 // (k) Shaft horsepower
119 LOSS=Pscl+Prel+Pcore+PFPS;
120 Pshaft=(S_R-LOSS)/746;
121
122 // (l) Shaft torque
123 T=5252*Pshaft/nr;
124
125 // (m) Effiency
126 eta=Pshaft/S_R*746;
127
128 // Display result on command window
129 printf("\n Slip = %0.4f ",s);
130 printf("\n Line current magnitude = %0.4f A",I1_Mag)
      ;
131 printf("\n Line current angle = %0.4f deg",I1_Ang);

```

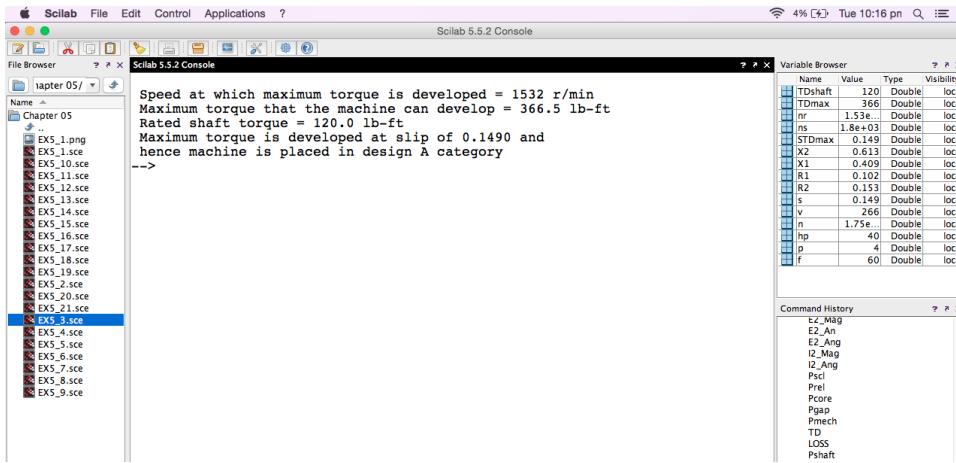


Figure 5.3: Computation of Speed at which maximum torque is developed and Maximum torque that the machine can develop and Rated shaft torque

```

132 printf("\n Apparent power = %0.0f W", S_R);
133 printf("\n Active power = %0.0f var", S_I);
134 printf("\n Reactive power = %0.0f VA", S_Mag);
135 printf("\n Power factor of the motor = %0.3f ", FP);
136 printf("\n Equivalent rotor current magnitude = %0.4f
A", I2_Mag);
137 printf("\n Equivalent rotor current angle = %0.4f deg
", I2_Ang);
138 printf("\n Stator copper loss = %0.0f W", Pscl);
139 printf("\n Rotor copper loss = %0.0f W", Prel);
140 printf("\n Core loss = %0.0f W", Pcore);
141 printf("\n Air-gap power = %0.0f W", Pgap);
142 printf("\n Mechanical power developed = %0.0f W",
Pmech);
143 printf("\n Developed torque = %0.2f lb-ft", TD);
144 printf("\n Shaft horsepower = %0.2f hp", Pshaft);
145 printf("\n Shaft torque = %0.1f lb-ft", T);
146 printf("\n Efficiency = %0.3f", eta);

```

Scilab code Exa 5.3 Computation of Speed at which maximum torque is developed and Maximum torque that the machine can develop and Rated shaft torque

```

1 // Example 5.3
2 // Computation of (a) Speed at which maximum torque
   is developed (b) Maximum
3 // torque that the machine can develop (c) Rated
   shaft torque (d) Which NEMA
4 // design fits this motor?
5 // Page No. 184
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 f=60;                                // Frequency in Hz
13 p=4;                                   // Number of poles
14 hp=40;                                 // Horsepower
15 n=1751;                                // Rated speed of machine
16 v=460/sqrt(3);                         // Voltage
17 s=0.1490;                               // Slip
18 R2=0.153;                               // Rotor resistance
19 R1=0.102;                               // Rotor reactance
20 X1=0.409;                               // Rotor reactance
21 X2=0.613;
22
23 // (a) Speed at which maximum torque is developed
24 STDmax=R2/(sqrt(R1^2+(X1+X2)^2));
25 ns=120*f/p;                            // stator speed
26 nr=ns*(1-s);
27
28 // (b) Maximum torque that the machine can develop

```

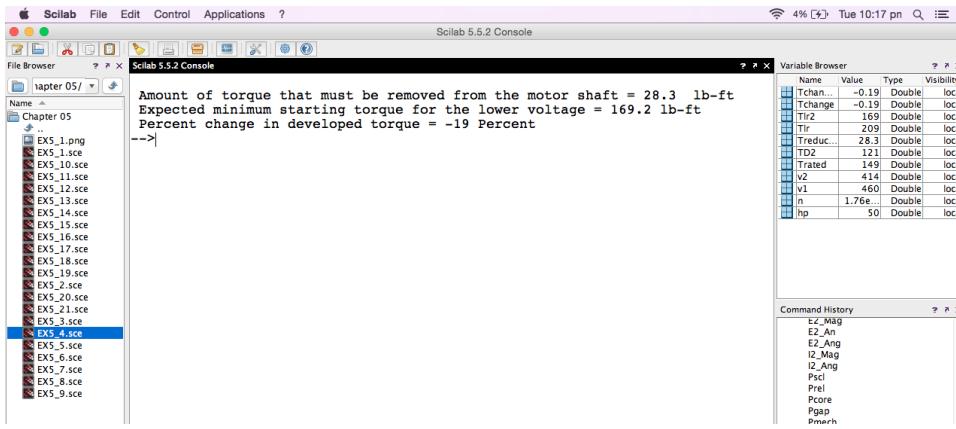


Figure 5.4: Computation of Amount of torque that must be removed from the motor shaft to maintain 1760 rpm and Expected minimum starting torque for the lower voltage and Percent change in developed torque

```

29 TDmax=(21.12*v^2)/(2*ns*(sqrt(R1^2+(X1+X2)^2)+R1));
30
31 // (c) Rated shaft torque
32 TDshaft=hp*5252/n;
33
34 // Display result on command window
35 printf("\n Speed at which maximum torque is
            developed = %0.0 f r/min ",nr);
36 printf("\n Maximum torque that the machine can
            develop = %0.1 f lb-ft ",TDmax);
37 printf("\n Rated shaft torque = %0.1 f lb-ft ",
            TDshaft);
38 printf("\n Maximum torque is developed at slip of
            0.1490 and \n hence machine is placed in design A
            category ");

```

Scilab code Exa 5.4 Computation of Amount of torque that must be removed from the motor shaft to maintain 1760 rpm and Expected minimum starting torque for the lower voltage and Percent change in developed torque

```
1 // Example 5.4
2 // Computation of (a) Amount of torque that must be
3 // removed from the motor
4 // shaft to maintain 1760r/min (b) Expected minimum
5 // startimg torque for the
6 // lower voltage (c) Percent change in developed
7 // torque caused by 10% drop in
8 // system voltage.
9 // Page No. 185
10
11
12 // Given data
13
14 hp=50;           // Horsepower
15 n=1760;          // Rated speed of machine
16 v1=460;
17
18
19 // (a) Amount of torque that must be removed from
20 // the motor shaft to maintain
21 v2=v1*0.90;
22 Trated=hp*5252/n;      //Rated torque
23 TD2=Trated*(v2/v1)^2;
24 Tred=Trated-TD2;
25
26 // (b) Expected minimum startimg torque for the
27 // lower voltage
28 Tlr=1.40*Trated;
29 Tlr2=Tlr*(v2/v1)^2;
```

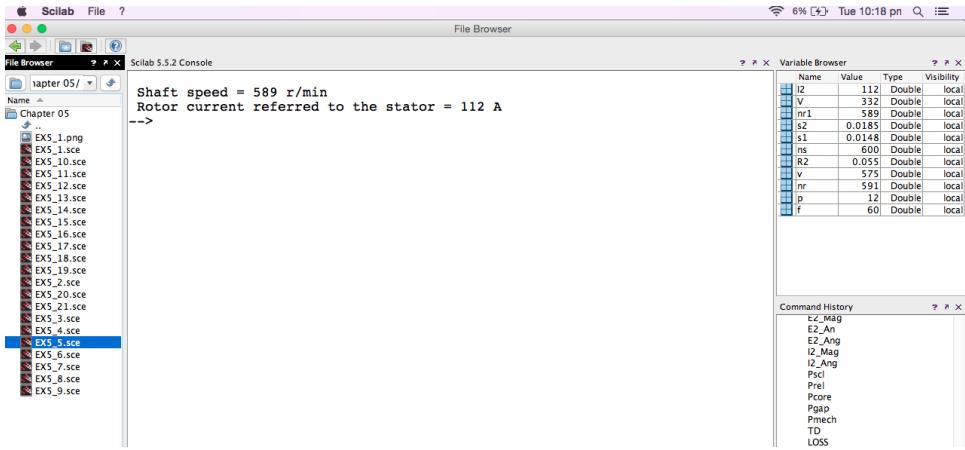


Figure 5.5: Computation of minimum value of Shaft speed and Rotor current referred to the stator

```

30
31 // (c) Percent change in developed torque caused by
   10% drop in system voltage
32
33 Tchange=(TD2-Trated)/Trated;
34 Tchanger=(Tl1r2-Tl1r)/Tl1r;
35
36 // Display result on command window
37 printf("\n Amount of torque that must be removed
         from the motor shaft = %0.1f lb-ft",Tred);
38 printf("\n Expected minimum starting torque for the
         lower voltage = %0.1f lb-ft ",Tl1r2);
39 printf("\n Percent change in developed torque = %0.0
         f Percent ",Tchanger*100);

```

Scilab code Exa 5.5 Computation of minimum value of Shaft speed and Rotor current referred to the stator

```

1 // Example 5.5
2 // Computation of minimum value of (a) Shaft speed (
3 // b) Rotor current referred
4 // to the stator
5 // Page No. 187
6
7 clc;
8 clear;
9
10 // Given data
11 f=60; // Frequency in Hz
12 p=12; // Number of poles
13 nr=591.1; // Rated speed of machine
14 v=575; // Voltage rating of the machine
15 R2=0.055;
16
17 // (a) Shaft speed
18 ns=120*f/p; // Speed (r/min)
19 s1=(ns-nr)/ns; // Slip 1
20 s2=1.25*s1; // Slip 2
21 nr1=ns*(1-s2);
22
23 // (b) Rotor current referred to the stator
24 V=v/sqrt(3);
25 I2=V*s2/R2;
26
27 // Display result on command window
28 printf("\n Shaft speed = %0.0f r/min ",nr1);
29 printf("\n Rotor current referred to the stator = %0
.0f A ",I2);

```

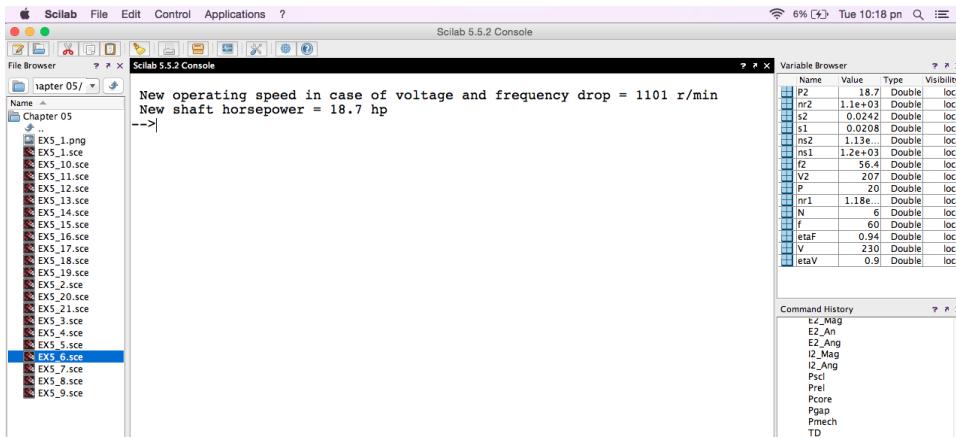


Figure 5.6: Determine new operating speed of a system and New shaft horsepower

Scilab code Exa 5.6 Determine new operating speed of a system and New shaft horsepower

```

1 // Example 5.6
2 // Determine (a) New operating speed if a system
   disturbance causes a 10% drop
3 // in voltage and 6% drop in frequency (b) New shaft
   horsepower.
4 // Page No. 190
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 etaV=0.90; // Efficiency related to
   voltage
12 V=230; // Voltage
13 etaF=0.94; // Efficiency related to
   voltage
14 f=60; // Frequency
15 N=6; // Number of poles

```

```

16 nr1=1175;           // Speed of motor
17 P=20;                // Horsepower of motor
18
19 // (a) New operating speed if a system disturbance
   causes a 10% drop in
20 // voltage and 6% drop in frequency
21 V2=etaV*V;           // New voltage after 10%
   drop
22 f2=etaF*f;           // New frequency after 6%
   drop
23 ns1=120*f/N;
24 ns2=120*0.94*f/N;
25 s1=(ns1-nr1)/ns1;    // Speed difference
26
27 s2=s1*((V/V2)^2)*(f2/f);
28 nr2=ns2*(1-s2);      // New speed
29
30 // (b) New shaft horsepower
31 P2=P*(nr2/nr1);      // With a constant torque
   load T2=T1
32
33 // Display result on command window
34 printf("\n New operating speed in case of voltage
   and frequency drop = %0.0f r/min ",nr2);
35 printf("\n New shaft horsepower = %0.1f hp ",P2);

```

Scilab code Exa 5.7 Determine expected locked rotor line current

```

1 // Example 5.7
2 // Determine expected locked-rotor line current
3 // Page No. 192
4
5 clc;

```

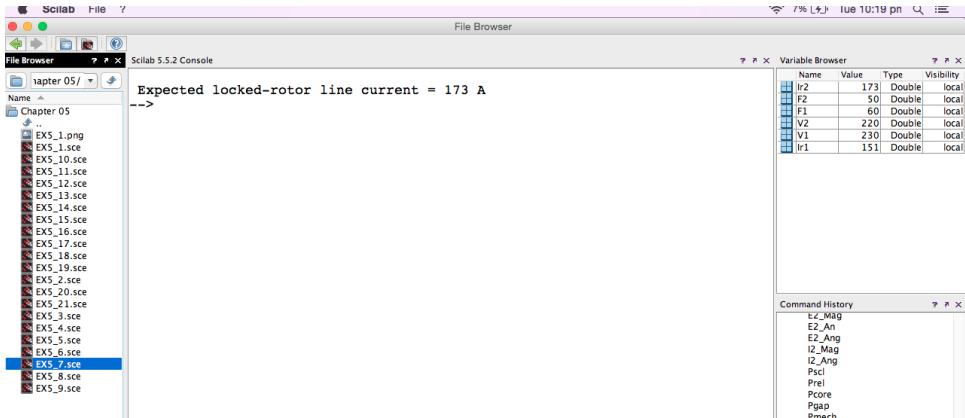


Figure 5.7: Determine expected locked rotor line current

```

6 clear;
7 close;
8
9 // Given data
10 Ir1=151;                                // Rated current
11 V1=230;                                  // Rated voltage
12 V2=220;                                  // Motor starting voltage
13 F1=60;                                   // Rated frequency
14 F2=50;                                   // Motor starting
                                             frequency
15
16 // Expected locked-rotor line current
17 Ir2=Ir1*((V2/F2)/(V1/F1));
18
19 // Display result on command window
20 printf("\n Expected locked-rotor line current = %0.0
          f A ",Ir2);

```

Scilab code Exa 5.8 Determine expected minimum locked rotor torque

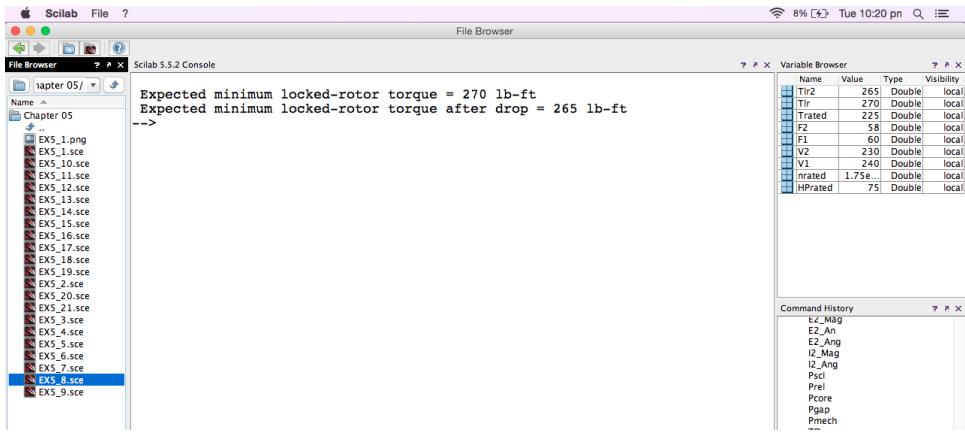


Figure 5.8: Determine expected minimum locked rotor torque and Repeat when voltage and frequency dropped to 230V and 58Hz

and Repeat when voltage and frequency dropped to 230V and 58Hz

```

1 // Example 5.8
2 // Determine (a) Expected minimum locked-rotor
   torque (b) Repeat (a) when
3 // voltage and frequency dropped to 230V and 58Hz
4 // Page No. 193
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 HPrated=75;           // Rated horsepower
12 nrated=1750;          // Rated speed
13 V1=240;               // Rated voltage
14 V2=230;               // Voltage after drop
15 F1=60;                // Rated frequency
16 F2=58;                // Frequency after drop
17
18 // (a) Expected minimum locked-rotor torque
19 Trated=5252*HPrated/nrated; // Rated torque

```



Figure 5.9: Determine shaft rpm and Slip

```

20 Tlr=Trated*1.2; // Minimum locked-
    rotor torque is 120% rated
21
22 // (b) Expected minimum locked-rotor torque when
    voltage and frequency dropped
23 // to 230V and 58Hz
24 Tlr2=Tlr*((V2/F2)^2)*((F1/V1)^2);
25
26 // Display result on command window
27 printf("\n Expected minimum locked-rotor torque = %0
    .0 f lb-ft",Tlr);
28 printf("\n Expected minimum locked-rotor torque
    after drop = %0.0 f lb-ft",Tlr2);

```

Scilab code Exa 5.9 Determine shaft rpm and Slip

```

1 // Example 5.9
2 // Determine (a) Shaft r/min (b) Slip
3 // Page No. 194

```

```

4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 F1=60;           // Rated frequency
11 N=4;            // Number of poles
12 F2=50;           // New frequency
13 ns=1770;         // Rated speed
14
15 // (a) Shaft r/min
16 ns60=120*F1/N;    // Speed at rated frequency
17 ns50=120*F2/N;    // Speed at 50 Hz frequency
18 s60=(ns60-ns)/ns60; // Slip at 60 Hz frequency
19
20 // Using eq. (5.16) and by solving .. s50=29.251/nr50
21 // Using eq. (4.3) and solving for nr50 we get the
   quadratic equation..
22 // Using various values of quadratic equations , we
   have
23 a=1;
24 b=-1500;
25 c=43876.5;
26 r1=(-b+sqrt(b^2-4*a*c))/(2*a); // Root 1
27
28 r2=(-b-sqrt(b^2-4*a*c))/(2*a); // Root 2
29 // Answer 'r2' is not valid
30
31 // (b) Slip
32 s50=(ns50-r1)/ns50;
33
34 // Display result on command window
35 printf("\n Shaft speed = %0.0f r/min",r1);
36 printf("\n Slip = %0.3f ",s50);

```

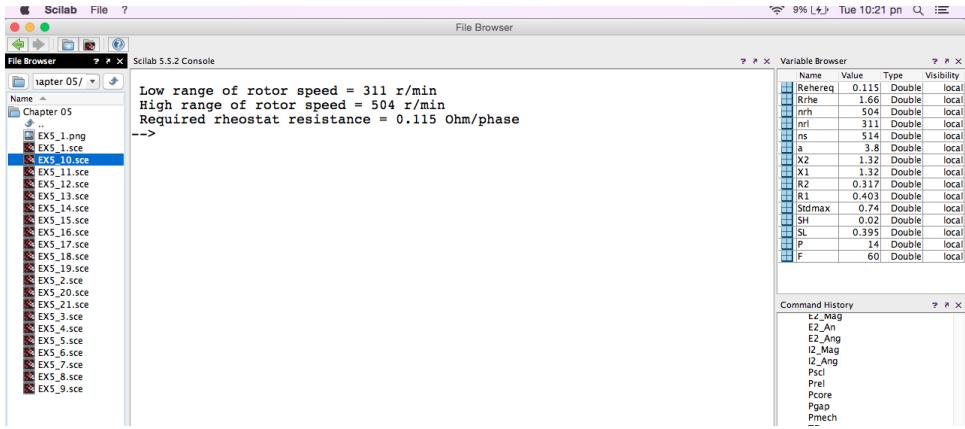


Figure 5.10: Determine range of rotor speed and Required rheostat resistance

Scilab code Exa 5.10 Determine range of rotor speed and Required rheostat resistance

```

1 // Example 5.10
2 // Determine (a) Range of rotor speed (b) Required
   rheostat resistance
3 // Page No. 198
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 F=60;                      // Frequency of motor
11 P=14;                       // Number of poles
12 SL=0.395;                   // Low speed point
13 SH=0.02;                     // High speed point
14 Stdmax=0.74;                // Value at which TD is

```

```

        maximum (from curve B)
15 R1=0.403;           // Motor resistance
16 R2=0.317;
17 X1=1.32;            // Motor reactance
18 X2=1.32;
19 a=3.8;              // Ratio of stator turns/
    phase to rotor turns/phase
20
21 // (a) Range of rotor speed
22 ns=120*F/P;          // Speed
23 nrl=ns*(1-SL);       // Rotor low speed
24 nrh=ns*(1-SH);       // Rotor high speed
25
26 // (b) Required rheostat resistance
27 Rrhe=Stdmax*(sqrt(R1^2+(X1+X2)^2))-R2;
28 Rehereq=Rrhe/a^2;
29
30 // Display result on command window
31 printf("\n Low range of rotor speed = %0.0f r/min" ,
    nrl);
32 printf("\n High range of rotor speed = %0.0f r/min" ,
    nrh);
33 printf("\n Required rheostat resistance = %0.3f Ohm/
    phase",Rehereq);

```

Scilab code Exa 5.11 Determine rotor frequency and Slip at which TD_{max} occurs and Rotor speed at half rated torque load and Required rheostat resistance and Rated torque

```

1 // Example 5.11
2 // Determine (a) Rotor frequency (b) Slip at which
    TDmax occurs (c) Rotor speed
3 // at 1/2 rated torque load (d) Required rheostat

```

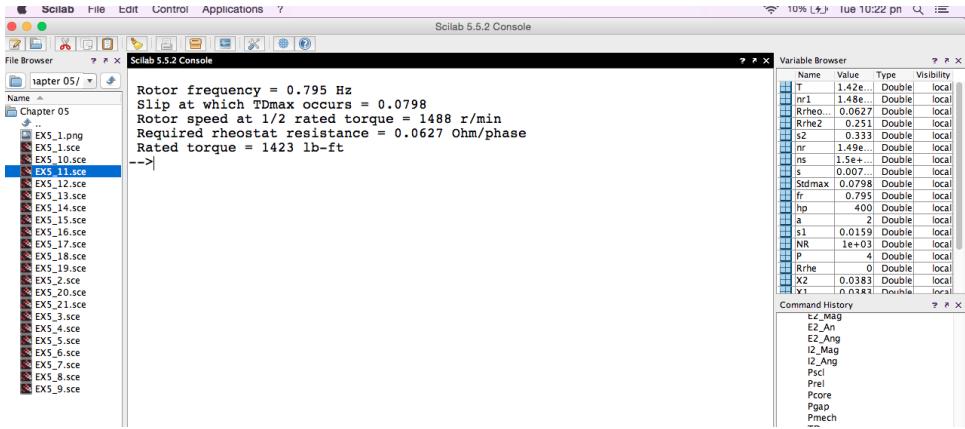


Figure 5.11: Determine rotor frequency and Slip at which TDmax occurs and Rotor speed at half rated torque load and Required rheostat resistance and Rated torque

```

    resistance (e) Rated torque
4 // Page No. 201
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 S=0.0159;                                // Slip
12 Fbr=50;                                   // Rated frequency
13 R1=0.00536;                               // Motor resistance
14 R2=0.00613;
15 X1=0.0383;                                // Motor reactance
16 X2=0.0383;
17 Rrhe=0;                                    // Initial rheostat
     resistance
18 P=4;                                       // Number of poles
19 NR=1000;                                   // Rated speed
20 s1=0.0159;                                // Slip of rheostat
21 a=2;                                       // Stator to rotor turns
     ratio

```

```

22 hp=400;                                // Motor horsepower
23
24 // (a) Rotor frequency
25 fr=S*Fbr;
26
27 // (b) Slip at which TDmax occurs
28 Stdmax=(R2+Rrhe)/sqrt(R1^2+(X1+X2)^2));
29
30 // (c) Rotor speed at 1/2 rated torque load
31 s=S*(0.5)*(R2/R2); // Rotor speed at 1/2 rated
32 torque
33 ns=120*Fbr/P;
34 nr=ns*(1-s); // Rotor speed
35
36 // (d) Required rheostat resistance
37 s2=(ns-NR)/ns;
38 Rrhe2=((s2/s1)*(1/0.5)*(R2+Rrhe))-R2; // rheostat
39 resistance
40 Rrheostat=Rrhe2/a^2;
41
42 // (e) Rated torque
43 nr1=ns*(1-s1); // Rated speed
44 T=hp*5252/nr1;
45
46 // Display result on command window
47 printf("\n Rotor frequency = %0.3f Hz",fr);
48 printf("\n Slip at which TDmax occurs = %0.4f ",Stdmax);
49 printf("\n Rotor speed at 1/2 rated torque = %0.0f r
50 /min",nr);
51 printf("\n Required rheostat resistance = %0.4f Ohm/
phase",Rrheostat);
52 printf("\n Rated torque = %0.0f lb-ft",T);

```

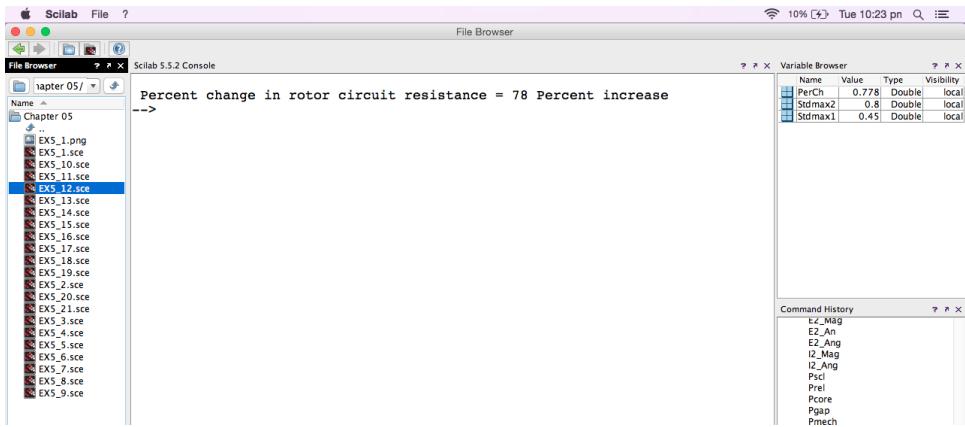


Figure 5.12: Determine the percent increase or decrease in rotor circuit resistance

Scilab code Exa 5.12 Determine the percent increase or decrease in rotor circuit resistance

```

1 // Example 5.12
2 // Determine the percent increase or decrease in
   rotor circuit resistance
3 // Page No. 202
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10
11 Stdmax1=0.45;           // Maximum torque condition 1
12 Stdmax2=0.80;           // Maximum torque condition 2
13

```

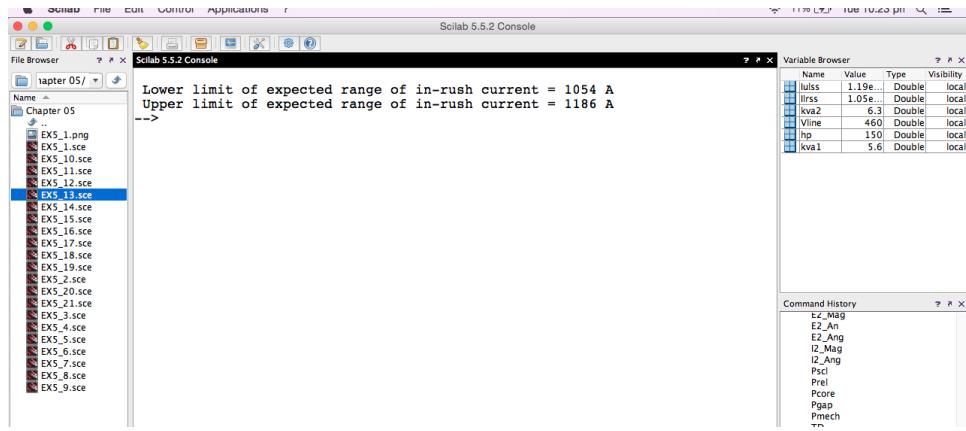


Figure 5.13: Determine the expected in rush current

```

14 // Percent increase or decrease in rotor circuit
   resistance
15
16 PerCh=1/(Stdmax1/Stdmax2);
17 PerCh=PerCh-1;
18
19 // Display result on command window
20 printf("\n Percent change in rotor circuit
   resistance = %0.0f Percent increase",PerCh*100);

```

Scilab code Exa 5.13 Determine the expected in rush current

```

1 // Example 5.13
2 // Determine the expected in-rush current
3 // Page No. 208
4
5 clc;
6 clear;
7 close;

```

```

8
9 // Given data
10 kva1=5.6; // KVA/hp lower limit from
11 table 5.9
12 hp=150; // Motor horsepower
13 Vline=460; // Line voltage
14 kva2=6.3; // KVA/hp upper limit from
15 table 5.9
16
17 // Lower limit of expected range of in-rush current
18 is
18 Ilrss=(kva1*hp*1000)/(\sqrt(3)*Vline);
19
20 // Upper limit of expected range of in-rush current
21 is
21 Iulss=(kva2*hp*1000)/(\sqrt(3)*Vline);
22
23 // Display result on command window
24 printf("\n Lower limit of expected range of in-rush
25 current = %0.0 f A",Ilrss);
25 printf("\n Upper limit of expected range of in-rush
current = %0.0 f A",Iulss);

```

Scilab code Exa 5.14 Determine percent voltage unbalance and Expected approximate temperature rise if operating at rated load in a 40 deg ambient and Expected insulation life and Required derating of motor to prevent shortening insulation life

```

1 // Example 5.14
2 // Determine (a) Percent voltage unbalance (b)
// Expected approximate temp. rise

```

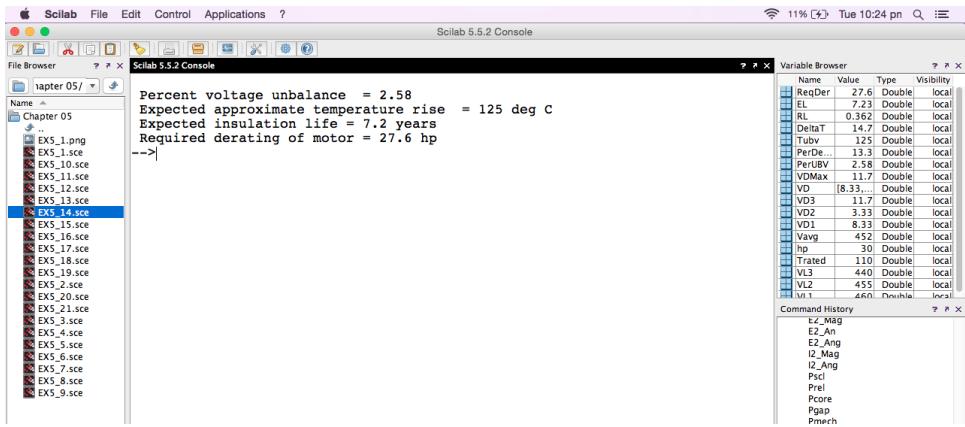


Figure 5.14: Determine percent voltage unbalance and Expected approximate temperature rise if operating at rated load in a 40 deg ambient and Expected insulation life and Required derating of motor to prevent shortening insulation life

```

3 // if operating at rated load in a 40 deg ambient (c)
   ) Expected insulation life
4 // (d) Required derating of motor to prevent
   shortening insulation life .
5 // Page No. 211
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 VL1=460;                      // Line voltage 1
13 VL2=455;                      // Line voltage 2
14 VL3=440;                      // Line voltage 3
15 Trated=110;                   // Rated temp. (from table
      5.8)
16 hp=30;                        // Motor horsepower
17
18 // (a) Percent voltage unbalance
19 Vavg=(VL1+VL2+VL3)/3;        // Average line voltage

```

```

20
21 VD1=abs(VL1-Vavg); // Voltage deviation
   from the average
22 VD2=abs(VL2-Vavg);
23 VD3=abs(VL3-Vavg);
24 VD=[VD1 VD2 VD3];
25 VDMax=max(VD); // Choose maximum value
   of voltage deviation
26 PerUBV=(VDMax/Vavg)*100;
27
28 // (b) Expected approximate temp. rise if operating
   at rated load in a 40 deg
29 PerDeltaT=2*PerUBV^2; // Percent change in
   temp.
30 Tubv=Trated*(1+(PerDeltaT/100));
31
32 // (c) Expected insulation life
33 DeltaT=Tubv-Trated; // Percent increase in
   motor temp.
34 RL=1/(2^(DeltaT/10)); // Relative life on
   insulation
35 EL=RL*20;
36
37 // (d) Required derating of motor to prevent
   shortening insulation life
38 ReqDer=hp*0.92;
39
40 // Display result on command window
41 printf("\n Percent voltage unbalance = %0.2f ", PerUBV);
42 printf("\n Expected approximate temperature rise = %0.0f deg C", Tubv);
43 printf("\n Expected insulation life = %0.1f years", EL);
44 printf("\n Required derating of motor = %0.1f hp", ReqDer);

```

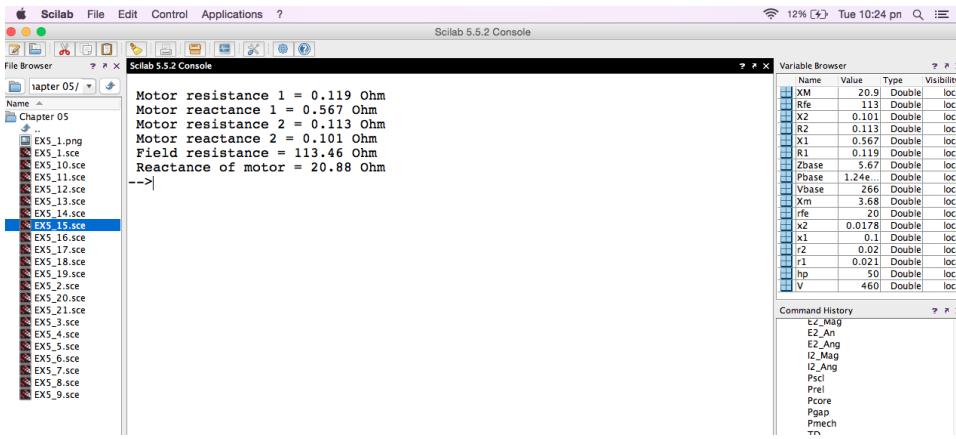


Figure 5.15: Determine the machine parameters in ohms

Scilab code Exa 5.15 Determine the machine parameters in ohms

```

1 // Example 5.15
2 // Determine the machine parameters in ohms
3 // Page No. 213
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 V=460;           // Motor voltage
11 hp=50;          // Motor horsepower
12 r1=0.021;        // Resistance
13 r2=0.020;        // Reactance
14 x1=0.100;        // Reactance
15 x2=0.0178;       // Reactance
16 rfe=20;

```

```

17 Xm=3.68;           // Motor reactance
18
19 // Machine parameters in ohms
20 Vbase=V/sqrt(3);    // Base voltage
21 Pbase=hp*746/3;     // Base power
22 Zbase=Vbase^2/Pbase; // Base impedance
23
24 R1=r1*Zbase;
25 X1=x1*Zbase;
26 R2=r2*Zbase;
27 X2=x2*Zbase;
28 Rfe=rfe*Zbase;
29 XM=Xm*Zbase;
30
31 // Display result on command window
32 printf("\n Motor resistance 1 = %0.3f Ohm",R1);
33 printf("\n Motor reactance 1 = %0.3f Ohm",X1);
34 printf("\n Motor resistance 2 = %0.3f Ohm",R2);
35 printf("\n Motor reactance 2 = %0.3f Ohm",X2);
36 printf("\n Field resistance = %0.2f Ohm",Rfe);
37 printf("\n Reactance of motor = %0.2f Ohm",XM);

```

Scilab code Exa 5.16 Determine R1 R2 X1 X2 XM and the combined core friction and windage loss and Express the no load current as a percent of rated current

```

1 // Example 5.16
2 // Determine (a) R1, R2, X1, X2, XM and the combined
   // core, friction and windage
3 // loss (b) Express the no-load current as a percent
   // of rated current
4 // Page No. 218
5

```

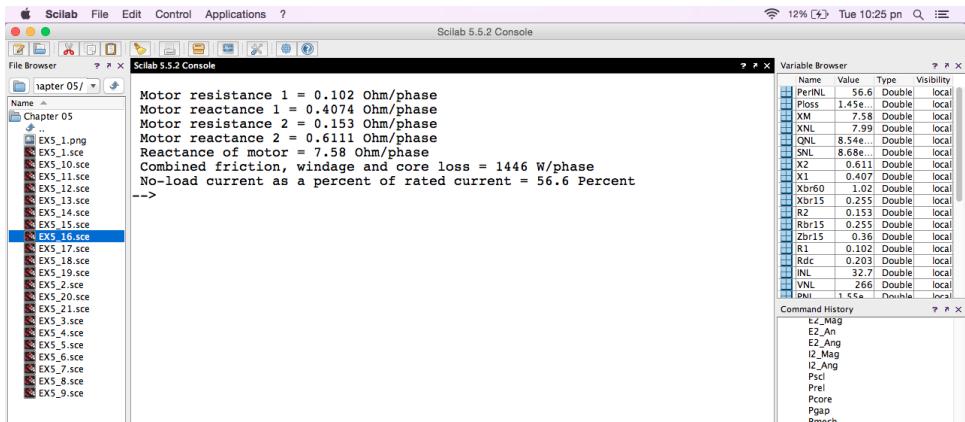


Figure 5.16: Determine R1 R2 X1 X2 XM and the combined core friction and windage loss and Express the no load current as a percent of rated current

```

6 clc;
7 clear;
8 close;
9
10 // Given data
11 P3ph=2573.4; // 3-ph power of
                 induction motor
12 Vline=36.2; // Line voltage
13 Iline=58; // Line current
14 P3phnl=4664.4; // No load power
15 Vlinenl=460; // No load line volatge
16 Ilinenl=32.7; // No load line current
17 Vdc=12; // DC voltage
18 Idc=59; // DC current
19 F1=60; // Rated frequency
20 F2=15; // Test frequency
21 Irated=57.8; // Rated current
22
23 // (a) R1, R2, X1, X2, XM and the combined core ,
// friction and windage loss
24 Pbr15=P3ph/3; // Power/phase
25 Vbr15=Vline/sqrt(3); // Voltage/phase
26 Ibr15=Iline;

```

```

27 PNL=P3phnl/3;                      // No load power/phase
28 VNL=Vlinenl/sqrt(3);                // No load voltage/
    phase
29 INL=Ilinenl;                      // No load current/
    phase
30
31 // Determination of R1
32 Rdc=Vdc/Idc;
33 R1=Rdc/2;
34
35 // Determination of R2
36 Zbr15=Vbr15/Ibr15;                  // Impedance
37 Rbr15=Pbr15/Ibr15^2;
38 R2=Rbr15-R1;
39
40 // Determination of X1 and X2
41 Xbr15=sqrt(Zbr15^2-Rbr15^2);
42 Xbr60=Xbr15*(F1/F2);
43 X1=0.4*Xbr60;                      // From Table 5.10
44 X2=0.6*Xbr60;
45
46 // Determination of XM
47 SNL=VNL*INL;
48 QNL=sqrt(SNL^2-PNL^2);
49 XNL=QNL/INL^2;
50 XM=XNL-X1;
51
52 // Determination of combined friction , windage and
    core loss
53 Ploss=PNL-(INL^2*R1);
54
55 // (b) No-load current as a percent of rated current
56 PerINL=INL*100/Irated;
57
58 // Display result on command window
59 printf("\n Motor resistance 1 = %0.3f Ohm/phase",R1)
    ;
60 printf("\n Motor reactance 1 = %0.4f Ohm/phase",X1);

```

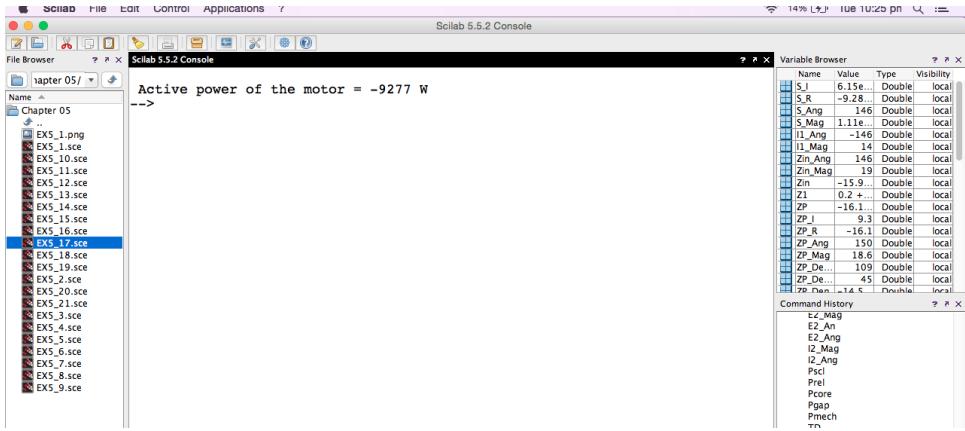


Figure 5.17: Determine the active power that the motor driven as an induction generator delivers to the system

```

61 printf("\n Motor resistance 2 = %0.3f Ohm/phase",R2)
       ;
62 printf("\n Motor reactance 2 = %0.4f Ohm/phase",X2);
63 printf("\n Reactance of motor = %0.2f Ohm/phase",XM)
       ;
64 printf("\n Combined friction , windage and core loss
           = %0.0f W/phase",Ploss);
65 printf("\n No-load current as a percent of rated
           current = %0.1f Percent",PerINL);

```

Scilab code Exa 5.17 Determine the active power that the motor driven as an induction generator delivers to the system

```

1 // Example 5.17
2 // Determine the active power that the motor , driven
      as an induction generator
3 // delivers to the system .
4 // Page No. 223

```

```

5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 ns=1200; // Speed
12 nr=1215;
13 R1=0.200; // Motor resistance
14 R2=0.250;
15 X1=1.20; // Motor reactance
16 X2=1.29;
17 Rfe=317; // Field resistance
18 XM=42; // Motor reactance
19 V=460; // Voltage rating
20
21 // Active power of the motor computation
22 s=(ns-nr)/ns; // Speed difference
23 Z2=(R2/s)+%i*X2;
24
25 // Complex to Polar form...
26 Z2_Mag=sqrt(real(Z2)^2+imag(Z2)^2); // Magnitude part
27 Z2_Ang = atan(imag(Z2),real(Z2))*180/%pi; // Angle part
28
29 Z0_Num_Mag=Rfe*XM; // Z0 numerator
30 Z0_Num_Ang=0+90;
31
32 Z0_Den_R=Rfe; // Z0 denominator
33 Z0_Den_I=XM;
34 Z0_Den=Z0_Den_R+%i*Z0_Den_I;
35 // Complex to Polar form...
36 Z0_Den_Mag=sqrt(real(Z0_Den)^2+imag(Z0_Den)^2); // Magnitude part
37 Z0_Den_Ang = atan(imag(Z0_Den),real(Z0_Den))*180/%pi;
; // Angle part
38

```

```

39 Z0_Mag=Z0_Num_Mag/Z0_Den_Mag; //  

   Magnitude of Z0  

40 Z0_Ang=Z0_Num_Ang-Z0_Den_Ang; // Angle of  

   Z0  

41  

42 // Polar to Complex form  

43 Z0_R=Z0_Mag*cos(-Z0_Ang*pi/180); // Real part  

   of complex number  

44 Z0_I=Z0_Mag*sin(Z0_Ang*pi/180); // Imaginary  

   part of complex number  

45  

46 // ZP computation  

47 ZP_Num_Mag=Z2_Mag*Z0_Mag; // ZP  

   numerator magnitude  

48 ZP_Num_Ang=Z2_Ang+Z0_Ang; // ZP  

   numerator angle  

49  

50 ZP_Den_R=real(Z2)+Z0_R; // Real part  

   of ZP denominator  

51 ZP_Den_I=imag(Z2)+Z0_I;  

52 ZP_Den=ZP_Den_R+%i*ZP_Den_I; // ZP in  

   complex form  

53  

54 // Complex to Polar form ...  

55 ZP_Den_Mag=sqrt(real(ZP_Den)^2+imag(ZP_Den)^2);  

   // Magnitude part  

56 ZP_Den_Ang = atan(imag(ZP_Den),real(ZP_Den))*180/pi  

   ; // Angle part  

57  

58 ZP_Mag=ZP_Num_Mag/ZP_Den_Mag; // Final  

   value of ZP in polar form  

59 ZP_Ang=ZP_Num_Ang-ZP_Den_Ang;  

60 // Polar to Complex form  

61 ZP_R=ZP_Mag*cos(-ZP_Ang*pi/180); // Real part  

   of complex number  

62 ZP_I=ZP_Mag*sin(ZP_Ang*pi/180); // Imaginary  

   part of complex number  

63

```

```

64 // Zin computation
65 ZP=ZP_R+%i*ZP_I; // Parallel
   impedance
66 Z1=R1+%i*X1;
67 Zin=Z1+ZP; // Input
   impedance
68 // Complex to Polar form...
69 Zin_Mag=sqrt(real(Zin)^2+imag(Zin)^2); // Magnitude part
70 Zin_Ang = atan(imag(Zin),real(Zin))*180/%pi; // Angle part
71
72 // I1 computation
73 I1_Mag=(V/sqrt(3))/Zin_Mag; // I1 magnitude
74 I1_Ang=0-Zin_Ang; // I1 angle
75
76 // S computation
77 S_Mag=3*(V/sqrt(3))*I1_Mag; // S magnitude
78 S_Ang=0-(-Zin_Ang); // S angle
79
80 // Polar to Complex form
81 S_R=S_Mag*cos(-S_Ang*%pi/180); // Real part of complex number
82 S_I=S_Mag*sin(S_Ang*%pi/180); // Imaginary part of complex number
83
84 // Display result on command window
85 printf("\n Active power of the motor = %0.0 f W",S_R)
;
```

Scilab code Exa 5.18 Computation of Locked rotor torque and the expected average in rush current and Repeat assuming motor is started at

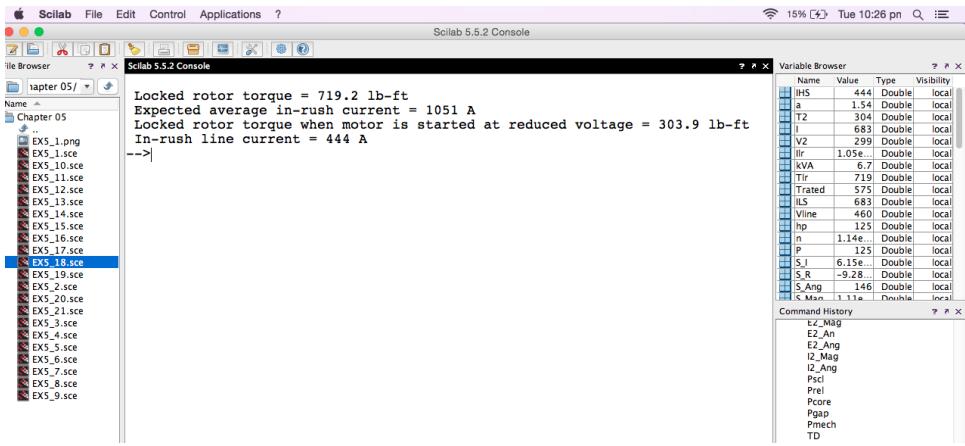


Figure 5.18: Computation of Locked rotor torque and the expected average in rush current and Repeat assuming motor is started at reduced voltage with 65 percent tap and In rush line current line current

reduced voltage with 65 percent tap and In rush line current line current

```

1 // Example 5.18
2 // Computation of (a) Locked rotor torque and the
3 // expected average in rush
4 // current (b) Repeat part (a) assuming motor is
5 // started at reduced voltage
6 // with 65% tap (c) In rush line current line
7 // current when starting at reduced
8 // voltage
9 // Page No. 231
10
11
12 // Given data
13 P=125; // Rated Voltage
14 n=1141; // Speed of machine
15 hp=125; // Horsepower rating of
           device

```

```

16 Vline=460;                      // Line voltage
17 ns=1200;                         // Stator speed
18 s=0.125;                          // Slip
19 ILS=683;                           // Current at low side
20
21 // (a) Locked rotor torque and the expected average
   in rush current
22 Trated=P*5252/(n);                // Rated torque
23 Tlr=1.25*Trated;                  // Locked rotor
   torque
24 kVA=(6.3+7.1)/2;
25 Ilr=(kVA*1000*hp)/(Vline*sqrt(3)); // In-rush
   current
26
27 // (b) Locked rotor torque and the expected average
   in rush current when motor
28 // is started at reduced voltage
29 V2=0.65*Vline;                   // Voltage
   impressed across the stator
30 I=Ilr*0.65;                      // Average in-rush
   current
31 T2=Tlr*(V2/Vline)^2;              // Locked rotor
   torque
32 nr=ns*(1-s);
33
34 // (c) In rush line current line current when
   starting at reduced voltage
35 a=1/0.65;                         // Bank ratio of
   autotransformer
36 IHS=ILS/a;
37
38 // Display result on command window
39 printf("\n Locked rotor torque = %0.1f lb-ft ",Tlr);
40 printf("\n Expected average in-rush current = %0.0f
   A ",Ilr);
41 printf("\n Locked rotor torque when motor is started
   at reduced voltage = %0.1f lb-ft ",T2);
42 printf("\n In-rush line current = %0.0f A",IHS);

```

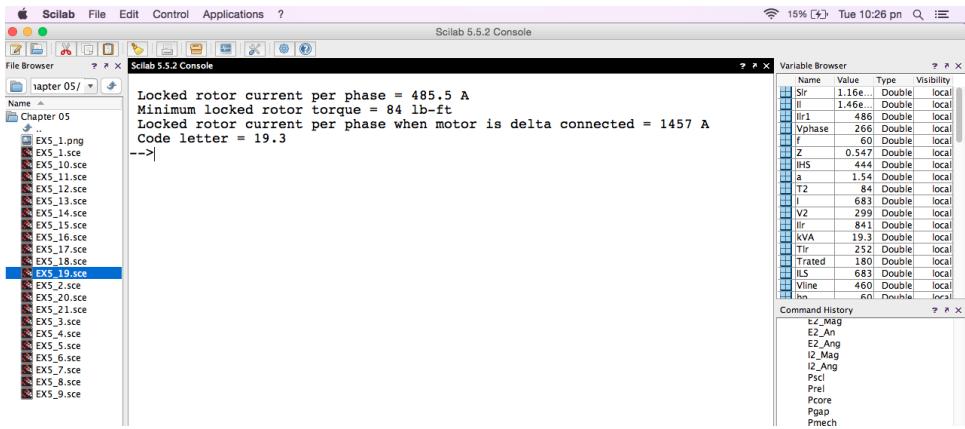


Figure 5.19: Computation of Locked rotor current per phase and minimum locked rotor torque when starting and Locked rotor current per phase when motor is delta connected and Code letter

Scilab code Exa 5.19 Computation of Locked rotor current per phase and minimum locked rotor torque when starting and Locked rotor current per phase when motor is delta connected and Code letter

```

1 // Example 5.19
2 // Computation of (a) Locked rotor current per phase
   and minimum locked rotor
3 // torque when starting (b) Locked rotor current per
   phase when motor is delta
4 // connected (c) Code letter
5 // Page No.233
6
7 clc;
8 clear all;
9 close;
10

```

```

11 // Given data
12 V=460;                      // Rated Voltage
13 Z=0.547;                     // Locked rotor impedance
14 n=1750;                      // Speed of machine
15 hp=60;                       // Horsepower rating of
                                device
16 f=60;                        // Frequency of motor
17
18
19 // (a) Locked rotor current per phase and minimum
   locked rotor torque
20 Vphase=V/sqrt(3);           // Voltage/phase
21 Ilr1=Vphase/Z;              // Locked rotor current/
                                phase
22 Trated=hp*5252/(n);        // Rated torque
23 Tlr=1.4*Trated;            // Locked rotor torque
24 T2=Tlr*(Vphase/V)^2;
25
26 // (b) Locked rotor current per phase when motor is
   delta connected
27 Ilr=V/Z;                    // Locked rotor current/
                                phase
28 I1=Ilr*sqrt(3);             // Line current
29
30 // (c) Code letter
31 Slr=sqrt(3)*V*I1/1000;     // Code letter at rated
                                voltage
32 kVA=Slr/f;
33
34 // Display result on command window
35
36 printf("\n Locked rotor current per phase = %0.1f A"
       ,Ilr1);
37 printf("\n Minimum locked rotor torque = %0.0f lb-ft"
       ,T2);
38 printf("\n Locked rotor current per phase when motor
       is delta connected = %0.0f A ",I1);
39 printf("\n Code letter = %0.1f",kVA);

```

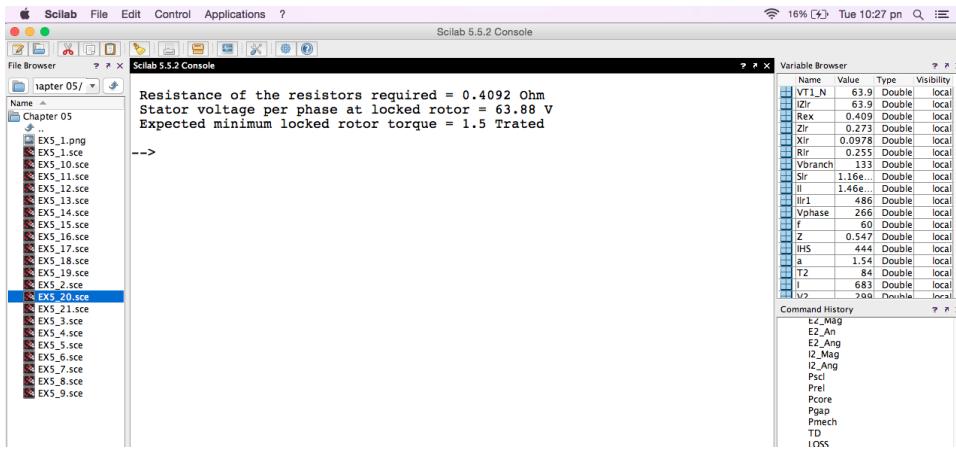


Figure 5.20: Computation of Resistance of the resistors required to limit the locked rotor current to 3 times rated current and Stator voltage per phase at locked rotor and Expected minimum locked rotor torque when starting as a percent of rated torque

Scilab code Exa 5.20 Computation of Resistance of the resistors required to limit the locked rotor current to 3 times rated current and Stator voltage per phase at locked rotor and Expected minimum locked rotor torque when starting as a percent of rated torque

```

1 // Example 5.20
2 // Computation of (a) Resistance of the resistors
   required to limit the locked
3 // rotor current to 3 times rated current (b) Stator
   voltage per phase at
4 // locked rotor (c) Expected minimum locked rotor
   torque when starting as a
5 // percent of rated torque
6 // Page No. 235

```

```

7
8 clc;
9 clear all;
10 close;
11
12 // Given data
13 Ilr=3*78;           // Locked rotor current
14 Vbranch=132.79;     // Branch voltage
15 Rlr=0.2549;         // Locked rotor resistance
16 Xlr=0.0978;         // Locked rotor impedance
17 f=60;                // Frequency of motor
18 Zlr=0.273;
19
20 // (a) Resistance of the resistors required to limit
   the locked rotor current
21 // to 3 times rated current
22 Rex=sqrt((Vbranch^2/Ilr^2)-(Rlr^2))-Xlr;
23
24 // (b) Stator voltage per phase at locked rotor
25 IZlr=Ilr*Zlr;
26 VT1_N=IZlr;
27
28 // (c) Expected minimum locked rotor torque when
   starting as a percent of
29 // rated torque
30 // From table 5.1 --> Minimum locked rotor torque =
   150% rated torque
31
32 // Display result on command window
33
34 printf("\n Resistance of the resistors required = %0
   .4f Ohm ",Rex);
35 printf("\n Stator voltage per phase at locked rotor
   = %0.2f V ",VT1_N);
36 disp('Expected minimum locked rotor torque = 1.5
   Trated');

```

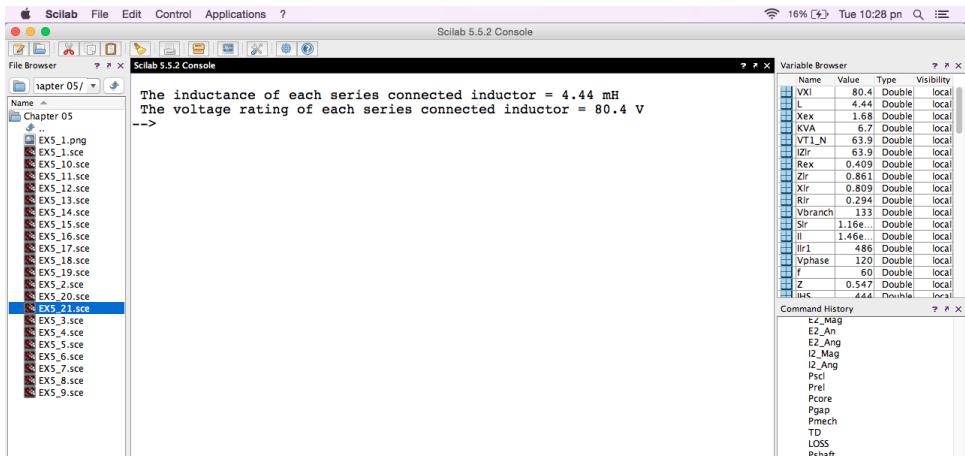


Figure 5.21: Computation of Inductance and voltage rating of each series connected inductor required to limit the starting current to approximately 2 times Rated

Scilab code Exa 5.21 Computation of Inductance and voltage rating of each series connected inductor required to limit the starting current to approximately 2 times Rated

```

1 // Example 5.21
2 // Computation of Inductance and voltage rating of
   each series connected
3 // inductor required to limit the starting current
   to approximately 2*Irated .
4 // Page No. 236
5
6 clc;
7 clear all;
8 close;
9
10 // Given data

```

```

11 KVA=6.7; // Average locked rotor
12 hp=7.5; // Motor horsepower
13 Vline=208; // Line voltage
14 I=48; // Total current
15 Rlr=0.294; // Locked rotor
16 Xlr=0.809; // Locked rotor
17 f=60; // Frequency of motor
18
19 // Corresponding approximate load current
20 Ilr=KVA*1000*hp/(sqrt(3)*Vline);
21 Vphase=Vline/sqrt(3); // Voltage/phase
22
23 // Applying ohm's law to one phase
24 Zlr=Vphase/Ilr; // Impedance
25 Xex=sqrt((Vphase^2/I^2)-(Rlr^2))-Xlr;
26 L=Xex/(2*pi*f);
27 L=L*10^03;
28 VXl=I*Xex;
29
30 // Display result on command window
31 printf("\n The inductance of each series connected
            inductor = %0.2f mH ",L);
32 printf("\n The voltage rating of each series
            connected inductor = %0.1f V ",VXl);

```

Chapter 6

Single Phase Induction Motors

Scilab code Exa 6.1 Determine Locked rotor current in each winding and Phase displacement angle between the two currents and Locked rotor torque in terms of the machine constant and External resistance required in series with the auxiliary winding and Locked rotor torque

```
1 // Example 6.1
2 // Determine (a) Locked rotor current in each
   winding (b) Phase displacement
3 // angle between the two currents (c) Locked rotor
   torque in terms of the
4 // machine constant (d) External resistance required
   in series with the auxillary
5 // winding in order to obtain a 30 degree phase
   displacement between the currents
6 // in the two windings (e) Locked rotor torque for
   the conditions in (d)
7 // (f) Percent increase in locked rotor torque due
   to the addition of external
8 // resistance
9 // Page No. 257
10
```

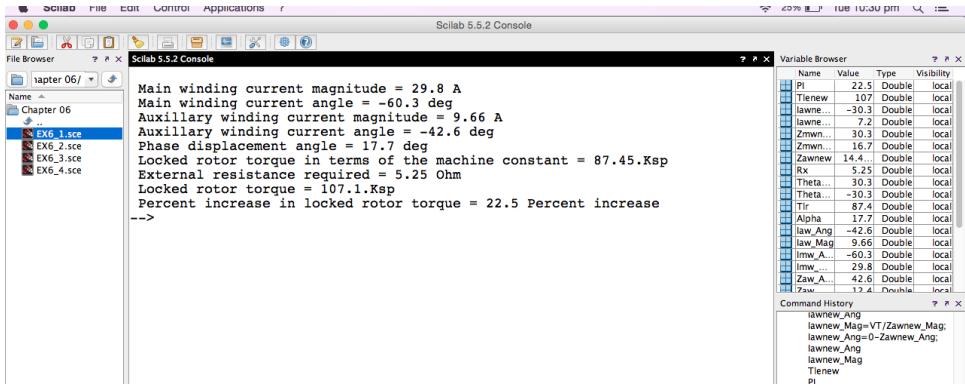


Figure 6.1: Determine Locked rotor current in each winding and Phase displacement angle between the two currents and Locked rotor torque in terms of the machine constant and External resistance required in series with the auxiliary winding and Locked rotor torque

```

11 clc;
12 clear;
13 close;
14
15 // Given data
16 Zmw=2.00+%i*3.50 // Main winding
    impedance
17 Zaw=9.15+%i*8.40 // Auxillary winding
    impedance
18 VT=120; // Transformer
    voltage
19 Xaw=8.40; // Auxillary winding
    reactance
20 Raw=9.15; // Auxillary winding
    resistance
21
22 // (a) Locked rotor current in each winding
23 // Main winding impedance in polar form
24 // Complex to Polar form...
25 Zmw_Mag=sqrt(real(Zmw)^2+imag(Zmw)^2); // Magnitude part

```

```

26 Zmw_Ang=atan(imag(Zmw),real(Zmw))*180/%pi; // Angle
      part
27
28 // Auxillary winding impedance in polar form
29 // Complex to Polar form...
30 Zaw_Mag=sqrt(real(Zaw)^2+imag(Zaw)^2); // Magnitude part
31 Zaw_Ang=atan(imag(Zaw),real(Zaw))*180/%pi; // Angle
      part
32
33 // Main winding current
34 Imw_Mag=VT/Zmw_Mag; // Main winding
      current magnitude
35 Imw_Ang=0-Zmw_Ang; // Main winding
      current angle
36
37 // Auxillary winding current
38 Iaw_Mag=VT/Zaw_Mag; // Auxillary
      winding current magnitude
39 Iaw_Ang=0-Zaw_Ang; // Auxillary
      winding current angle
40
41 // (b) Phase displacement angle between the two
      currents
42 Alpha=abs(Imw_Ang-Iaw_Ang);
43
44 // (c) Locked rotor torque in terms of the machine
      constant
45 Tlr=Imw_Mag*Iaw_Mag*sind(Alpha);
46
47 // (d) External resistance required in series with
      the auxillary winding in
48 // order to obtain a 30 degree phase displacement
      between the currents in the
49 // two windings
50 Theta_awi=Imw_Ang+30; // Required phase angle
51 Theta_awz=-Theta_awi;
52 Rx=(Xaw/tand(Theta_awz))-Raw;

```

```

53
54 // (e) Locked rotor torque for the conditions in (d)
55 Zawnew=Raw+Rx+%i*Xaw;           // Auxillary
      winding impedance
56 // Complex to Polar form...
57 Zmwnew_Mag=sqrt(real(Zawnew)^2+imag(Zawnew)^2);
      // Magnitude part
58 Zmwnew_Ang=atan(imag(Zawnew),real(Zawnew))*180/%pi;
      // Angle part
59
60 Iawnew_Mag=VT/Zmwnew_Mag;       // Auxillary
      winding current magnitude
61 Iawnew_Ang=0-Zmwnew_Ang;        // Auxillary
      winding current magnitude
62 Tlenew=Imw_Mag*Iawnew_Mag*sind(30);
63
64 // (f) Percent increase in locked rotor torque due
      to the addition of external
65 // resistance
66 PI=(Tlenew-Tlr)/Tlr*100;
67
68
69 // Display result on command window
70 printf("\n Main winding current magnitude = %0.1f A
      ",Imw_Mag);
71 printf("\n Main winding current angle = %0.1f deg ",
      Imw_Ang);
72 printf("\n Auxillary winding current magnitude = %0
      .2f A ",Iaw_Mag);
73 printf("\n Auxillary winding current angle = %0.1f
      deg ",Iaw_Ang);
74 printf("\n Phase displacement angle = %0.1f deg ",
      Alpha);
75 printf("\n Locked rotor torque in terms of the
      machine constant = %0.2f.Ksp ",Tlr);
76 printf("\n External resistance required = %0.2f Ohm
      ",Rx);
77 printf("\n Locked rotor torque = %0.1f.Ksp ",Tlenew)

```

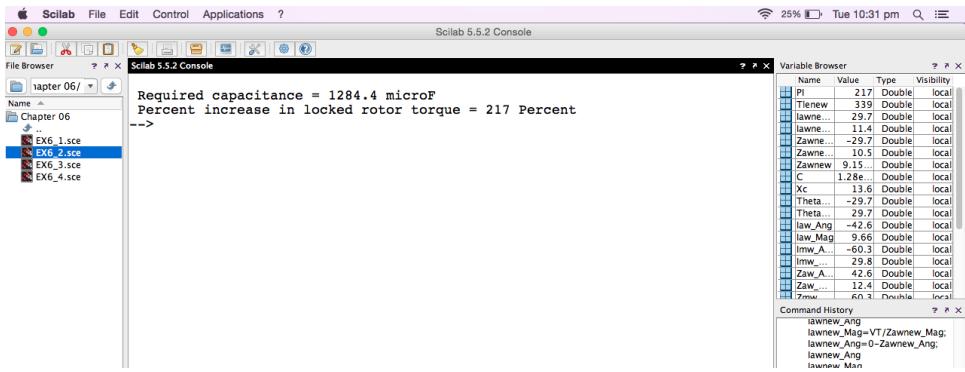


Figure 6.2: Determine Capacitance required in series with the auxiliary winding and Locked rotor torque

```

;
78 printf("\n Percent increase in locked rotor torque =
%0.1f Percent increase ",PI);

```

Scilab code Exa 6.2 Determine Capacitance required in series with the auxiliary winding and Locked rotor torque

```

1 // Example 6.2
2 // Determine (a) Capacitance required in series with
   // the auxillary winding
3 // in order to obtain a 90 degree phase displacement
   // between the current in
4 // the main winding and the current in the auxillary
   // winding at locked rotor
5 // (b) Locked rotor torque in terms of the machine
   // constant
6 // Page No. 265
7
8 clc;
9 clear;

```

```

10 close;
11
12 // Given data
13 Zmw=2.00+%i*3.50 // Main winding
   impedance
14 Zaw=9.15+%i*8.40 // Auxillary winding
   impedance
15 VT=120; // Transformer
   voltage
16 Xaw=8.40; // Auxillary winding
   reactance
17 Raw=9.15; // Auxillary winding
   resistance
18 f=60; // Frequency
19 Tlr=107.1; // Original torque
20
21 // (a) Capacitance required in series with the
   auxillary winding
22 // Main winding impedance in polar form
23 // Complex to Polar form...
24 Zmw_Mag=sqrt(real(Zmw)^2+imag(Zmw)^2); // Magnitude part
25 Zmw_Ang=atan(imag(Zmw),real(Zmw))*180/%pi; // Angle part
26
27 // Auxillary winding impedance in polar form
28 // Complex to Polar form...
29 Zaw_Mag=sqrt(real(Zaw)^2+imag(Zaw)^2); // Magnitude part
30 Zaw_Ang=atan(imag(Zaw),real(Zaw))*180/%pi; // Angle part
31
32 // Main winding current
33 Imw_Mag=VT/Zmw_Mag; // Main winding
   current magnitude
34 Imw_Ang=0-Zmw_Ang; // Main winding
   current angle
35

```

```

36 // Auxillary winding current
37 Iaw_Mag=VT/Zaw_Mag; // Auxillary
   winding current magnitude
38 Iaw_Ang=0-Zaw_Ang; // Auxillary
   winding current angle
39
40 Theta_awi=90-60.26; // Required phase
   angle
41 Theta_awz=-Theta_awi;
42
43 Xc=Xaw-Raw*tand(Theta_awz); // Capacitive
   reactance
44
45 C=1/2*%pi*f*Xc; // Required
   capacitance
46
47
48 // (b) Locked rotor torque in terms of the machine
   constant
49 Zawnew=Raw+%i*Xaw-%i*Xc; // Auxillary
   winding impedance
50 // Complex to Polar form...
51 Zawnew_Mag=sqrt(real(Zawnew)^2+imag(Zawnew)^2);
   // Magnitude part
52 Zawnew_Ang=atan(imag(Zawnew),real(Zawnew))*180/%pi;
   // Angle part
53
54 Iawnew_Mag=VT/Zawnew_Mag; // Auxillary
   winding current magnitude
55 Iawnew_Ang=0-Zawnew_Ang; // Auxillary
   winding current magnitude
56
57 Tlenew=Imw_Mag*Iawnew_Mag*sind(90);
58
59 // Percent change increase in locked rotor torque
60 PI=(Tlenew-Tlr)/Tlr*100;
61
62

```

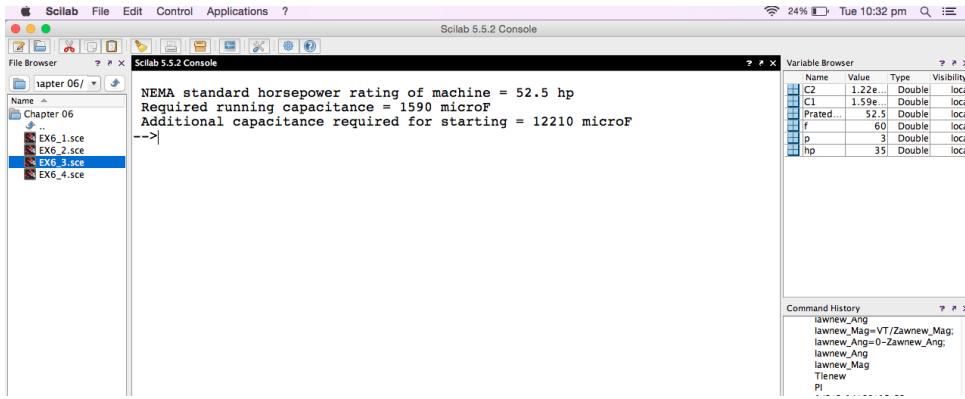


Figure 6.3: Determine NEMA standard horsepower rating of machine and Required running capacitance and Additional capacitance required for starting

```

63 // Display result on command window
64 printf("\n Required capacitance = %0.1f microF ",C);
65 printf("\n Percent increase in locked rotor torque =
           %0.0f Percent",PI);
66
67 //Note: Capacitor computation is wrong in the book

```

Scilab code Exa 6.3 Determine NEMA standard horsepower rating of machine and Required running capacitance and Additional capacitance required for starting

```

1 // Example 6.3
2 // Determine (a) NEMA standard horsepower rating of
   machine (b) Required
3 // running capacitance (c) Additional capacitance
   required for starting
4 // Page No. 271
5

```

```

6 clc;
7 clear;
8 close;
9
10 // Given data
11 hp=35;           // Power in hp
12 p=3;            // Number of phase
13 f=60;           // Frequency
14
15
16 // (a) NEMA standard horsepower rating of machine
17
18 Prated3ph=hp*p/2;
19
20 // (b) Required running capacitance
21
22 C1=26.5*f;
23
24 // (c) Additional capacitance required for starting .
25
26 C2=230*f-C1;
27
28 // Display result on command window
29 printf("\n NEMA standard horsepower rating of
      machine = %0.1f hp ",Prated3ph);
30 printf("\n Required running capacitance = %0.0f
      microF ",C1);
31 printf("\n Additional capacitance required for
      starting = %0.0f microF ",C2);

```

Scilab code Exa 6.4 Computation of Motor line current and motor phase current and Motor line current and motor phase current if one line opens and Line and phase currents if the power factor is 82 percent

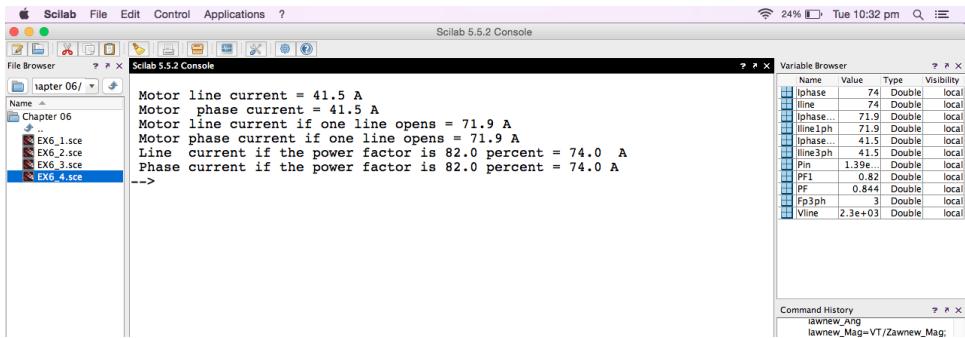


Figure 6.4: Computation of Motor line current and motor phase current and Motor line current and motor phase current if one line opens and Line and phase currents if the power factor is 82 percent

```

1 // Example 6.4
2 // Computation of (a) Motor line current and motor
3 // phase current (b) Motor line
4 // current and motor phase current if one line opens
5 // (c) Line and phase
6 // currents if the power factor when single phasing
7 // is 82.0 percent.
8 // Page No. 274
9
10
11 // Given data
12 Vline=2300; // Line voltage
13 Fp3ph=3; // Frequency of three
14 PF=0.844; // Power factor
15 PF1=0.820; // 82.2 percent power
16 Pin=350*746/(0.936*2); // Input power
17
18
19 // (a) Motor line current and motor phase current

```

```

20
21 Iline3ph=Pin/(sqrt(3)*Vline*PF);
22 Iphase3ph=Iline3ph;
23
24 // (b) Motor line current and motor phase current if
   one line opens
25
26 Iline1ph=(sqrt(3)*Iline3ph*PF)/PF;
27 Iphase1ph=Iline1ph;
28
29 // (c) Line and phase currents if the power factor
   when single phasing is 82.0 percent.
30
31 Iline=(Iline1ph*PF)/PF1;
32 Iphase=Iline;
33
34 // Display result on command window
35 printf("\n Motor line current = %0.1f A ",Iline3ph);
36 printf("\n Motor phase current = %0.1f A ",
   Iphase3ph);
37 printf("\n Motor line current if one line opens = %0
   .1f A ",Iline1ph);
38 printf("\n Motor phase current if one line opens =
   %0.1f A ",Iphase1ph);
39 printf("\n Line current if the power factor is 82.0
   percent = %0.1f A",Iline);
40 printf("\n Phase current if the power factor is 82.0
   percent = %0.1f A ",Iphase);

```

Chapter 7

Speciality Machines

Scilab code Exa 7.1 Determine Torque load on the shaft and Torque angle if the voltage drops to 224V

```
1 // Example 7.1
2 // Determine (a) Torque load on the shaft (b) Torque
   angle if the voltage
3 // drops to 224V (c) Will the rotor pull out of
   synchronism?
4 // Page No. 282
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 f=60;           // Frequency
12 P=4;            // Number of poles
13 Pshaft=10;      // Shaft power in hp
14 V1=240;         // Rated voltage
15 V2=224;         // New voltage
16 phirel1=30;     // Torque angle
```

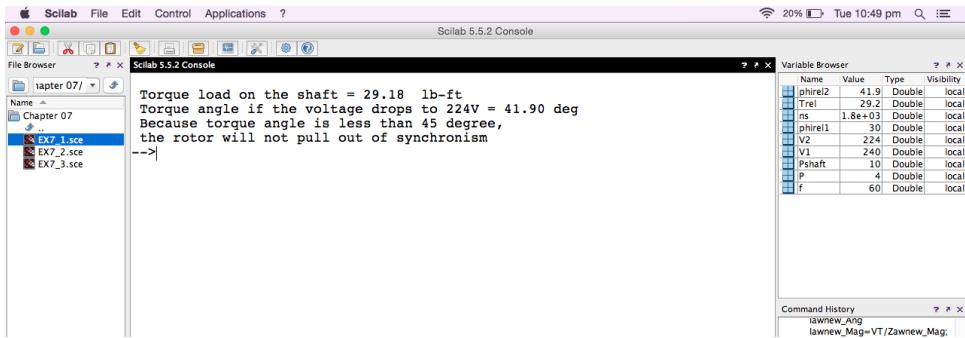


Figure 7.1: Determine Torque load on the shaft and Torque angle if the voltage drops to 224V

```

17
18
19 // (a) Torque load on the shaft
20 ns=120*f/P; // speed of machine
21 Trel=Pshaft*5252/ns;
22
23
24 // (b) Torque angle if the voltage drops to 224V
25 phirel2=asind((V1^2/V2^2)*sind(2*phirel1))/2
26
27 // Display result on command window
28 printf("\n Torque load on the shaft = %0.2f lb-ft ",Trel);
29 printf("\n Torque angle if the voltage drops to 224V
           = %0.2f deg ",phirel2);
30 printf("\n Because torque angle is less than 45
           degree, \n the rotor will not pull out of
           synchronism ")

```

Scilab code Exa 7.2 Determine Resolution and Number of steps required for the rotor and Shaft speed

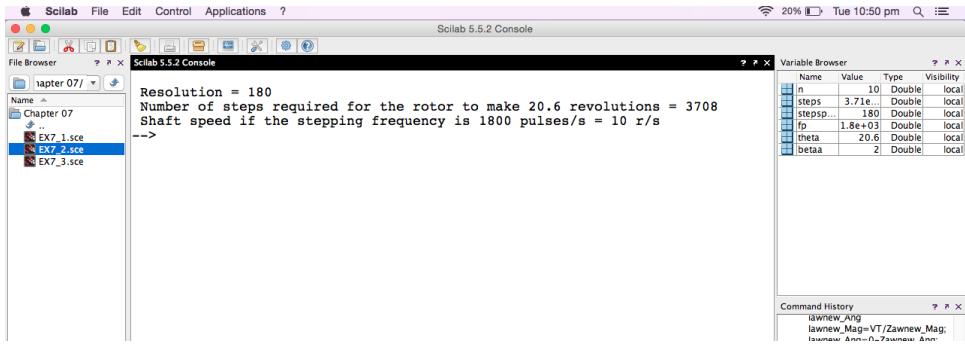


Figure 7.2: Determine Resolution and Number of steps required for the rotor and Shaft speed

```

1 // Example 7.2
2 // Determine (a) Resolution (b) Number of steps
   required for the rotor to make
3 // 20.6 revolutions (c) Shaft speed if the stepping
   frequency is 1800 pulses/s
4 // Page No. 287
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 betaaa=2;           // Step angle
12 theta=20.6;         // Number of revolutions
13 fp=1800;            // Stepping frequency
14
15
16 // (a) Resolution
17 stepsperrev=360/betaaa; // Speed of machine
18
19
20 // (b) Number of steps required for the rotor to
   make 20.6 revolutions
21 steps=theta*360/betaaa;
22

```

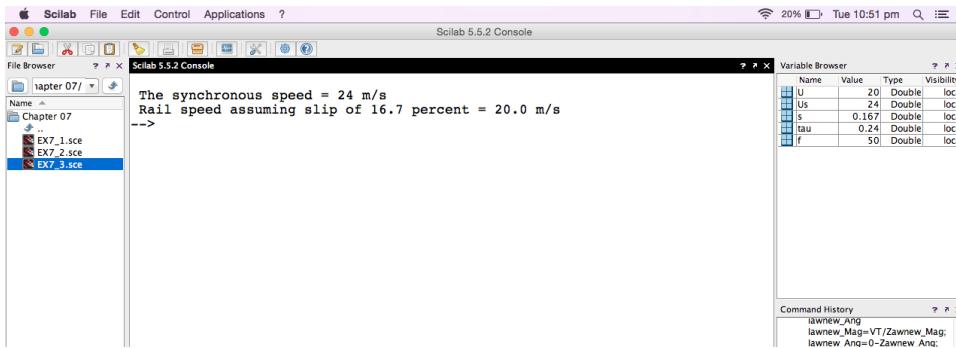


Figure 7.3: Determine Synchronous speed and Rail speed

```

23
24 // (c) Shaft speed if the stepping frequency is 1800
   pulses/s.
25 n=betaaa*fp/360;
26
27
28 // Display result on command window
29 printf("\n Resolution = %0.0f ",stepsperrev);
30 printf("\n Number of steps required for the rotor to
   make 20.6 revolutions = %0.0f ",steps);
31 printf("\n Shaft speed if the stepping frequency is
   1800 pulses/s = %0.0f r/s ",n);

```

Scilab code Exa 7.3 Determine Synchronous speed and Rail speed

```

1 // Example 7.3
2 // Determine (a) Synchronous speed (b) Rail speed
   assuming slip of 16.7%
3 // Page No. 299
4
5 clc;

```

```

6 clear;
7 close;
8
9 // Given data
10 f=50;           // Frequency of machine
11 tau=0.24;       // Pole pitch
12 s=0.167;        // Slip
13
14 // (a) The synchronous speed
15 Us=2*tau*f;
16
17 // (b) Rail speed assuming slip of 16.7 percent
18 U=Us*(1-s);
19
20
21 // Display result on command window
22 printf("\n The synchronous speed = %0.0f m/s ",Us);
23 printf("\n Rail speed assuming slip of 16.7 percent
         = %0.1f m/s ",U);

```

Chapter 8

Synchronous Motors

Scilab code Exa 8.1 Determine Developed torque and Armature current and Excitation voltage and Power angle and Maximum torque

```
1 // Example 8.1
2 // Determine (a) Developed torque (b) Armature
   current (c) Excitation voltage
3 // (d) Power angle (e) Maximum torque
4 // Page No. 317
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 f=60;                      // Operating frequency
12 P=4;                        // Number of poles
13 Pmech=100;                  // Mechanical power
14 eta=0.96;                   // Efficiency
15 FP=0.80;                    // Power factor leading
16 V=460;                      // Motor voltage
17 Xs_Mag=2.72;                // Synchronous reactnace
```

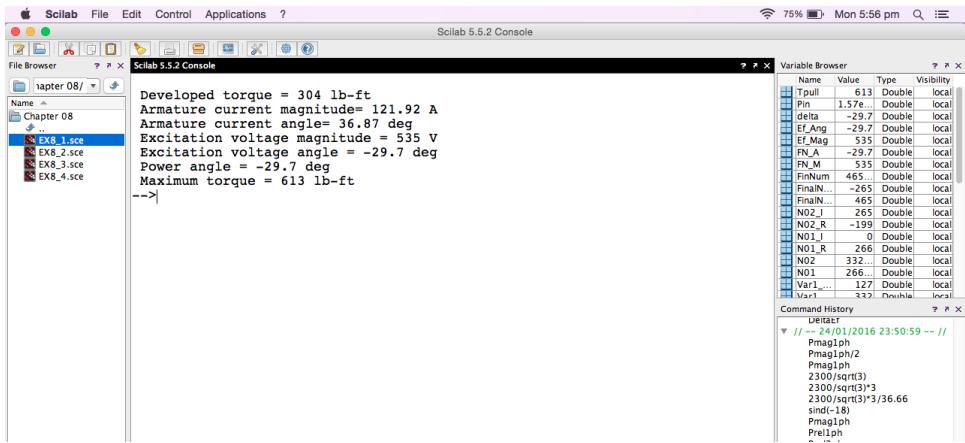


Figure 8.1: Determine Developed torque and Armature current and Excitation voltage and Power angle and Maximum torque

```

magnitude
18 Xs_Ang=90;                                // Synchronous reactance
      magnitude
19 deltaPull=-90;                             // Pullout power angle
20 // (a) Developed torque
21 ns=120*f/P;                               // Synchronous speed
22 Td=5252*Pmech/(ns*eta);
23
24
25 // (b) Armature current
26 S=Pmech*746/(eta*FP);
27 Theta=-acosd(FP);                         // Power factor angle (
      negative as FP is leading)
28 V1phi=V/sqrt(3);                          // Single line voltage
29 S1phi_Mag=S/3;                            // Magnitude
30 S1phi_Ang=Theta;                          // Angle
31 VT_Mag=V1phi;
32 VT_Ang=0;
33 Ia_Mag=S1phi_Mag/VT_Mag;                 // Armature current
      magnitude
34 Ia_Ang=S1phi_Ang-VT_Ang;                // Armature current angle
35 Ia_Ang=-Ia_Ang;                           // Complex conjugate of

```

Ia

```
36
37 // (c) Excitation voltage
38 Var1_Mag=Ia_Mag*Xs_Mag;
39 Var1_Ang=Ia_Ang+Xs_Ang;
40
41 //////////
42 N01=VT_Mag+%i*VT_Ang;
43 N02=Var1_Mag+%i*Var1_Ang;
44 // Polar to Complex form
45
46 N01_R=VT_Mag*cos(-VT_Ang*%pi/180); // Real part of
   complex number 1
47 N01_I=VT_Mag*sin(VT_Ang*%pi/180); //Imaginary part
   of complex number 1
48
49 N02_R=Var1_Mag*cos(-Var1_Ang*%pi/180); // Real part
   of complex number 2
50 N02_I=Var1_Mag*sin(Var1_Ang*%pi/180); //Imaginary
   part of complex number 2
51
52 FinalNo_R=N01_R-N02_R;
53 FinalNo_I=N01_I-N02_I;
54 FinNum=FinalNo_R+%i*FinalNo_I;
55 // Complex to Polar form...
56
57 FN_M=sqrt(real(FinNum)^2+imag(FinNum)^2); //
   Magnitude part
58 FN_A = atan(imag(FinNum),real(FinNum))*180/%pi; //
   Angle part
59 //////////
60 Ef_Mag=FN_M;
61 Ef_Ang=FN_A;
62 // (d) Power angle
63 delta=Ef_Ang;
64
65 // (e) Maximum torque
66 Pin=3*(-VT_Mag*Ef_Mag/Xs_Mag)*sind(deltaPull); //
```

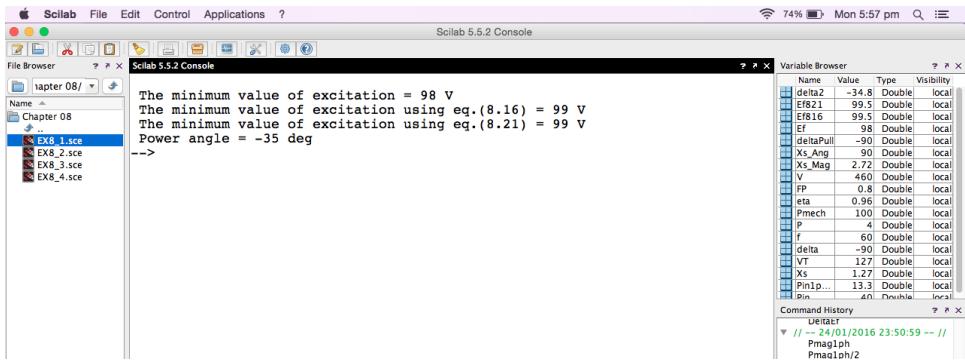


Figure 8.2: Determine minimum value of excitation and Repeat calculations using eq 8 16 and 8 21 and Power angle

```

Active power input
67 Tpull=5252*Pin/(746*ns);
68
69
70
71 // Display result on command window
72 printf("\n Developed torque = %0.0f lb-ft ",Td);
73 printf("\n Armature current magnitude= %0.2f A ",
    Ia_Mag);
74 printf("\n Armature current angle= %0.2f deg ",
    Ia_Ang);
75 printf("\n Excitation voltage magnitude = %0.0f V ",
    Ef_Mag);
76 printf("\n Excitation voltage angle = %0.1f deg ",
    Ef_Ang);
77 printf("\n Power angle = %0.1f deg ",delta);
78 printf("\n Maximum torque = %0.0f lb-ft ",Tpull);

```

Scilab code Exa 8.2 Determine minimum value of excitation and Repeat calculations using eq 8 16 and 8 21 and Power angle

```

1 // Example 8.2
2 // Determine (a) The minimum value of excitation
   that will maintain
3 // synchronism (b) Repeat (a) using eq.(8.16) (c)
   Repeat (a) using eq.(8.21)
4 // (d) Power angle if the field excitation voltage
   is increased to 175% of the
5 // stability limit determined in (c)
6 // Page No. 322
7
8 clc;
9 clear;
10 close;
11
12 // Given data
13 Pin=40;                                // Input power
14 Pin1phase=40/3;                         // Single phase power
15 Xs=1.27;                               // Synchronous reactnace
16 VT=220/sqrt(3);                        // Voltage
17 delta=-90;                             // Power angle
18
19 f=60;                                  // Operating frequency
20 P=4;                                    // Number of poles
21 Pmech=100;                            // Mechanical power
22 eta=0.96;                             // Efficiency
23 FP=0.80;                              // Power factor leading
24 V=460;                                 // Motor voltage
25 Xs_Mag=2.72;                           // Synchronous reactnace
   magnitude
26 Xs_Ang=90;                            // Synchronous reactnace
   magnitude
27 deltaPull=-90;                          // Pullout power angle
28
29 // (a) The minimum value of excitation that will
   maintain synchronism
30 Ef=98;                                 // From the graph (
   Figure 8.13)
31

```

```

32 // (b) The minimum value of excitation using eq
33 .(8.16)
34 Ef816=-Pin*Xs*746/(3*VT*sind(delta));
35
36 // (c) The minimum value of excitation using eq
37 .(8.21)
38 Ef821=Xs*Pin1phase*746/(VT);
39 // (d) Power angle if the field excitation voltage
40 is increased to 175%
41 delta2=Ef816*sind(delta)/(1.75*Ef816);
42 delta2=asind(delta2);
43 // Display result on command window
44 printf("\n The minimum value of excitation = %0.0f V
45 " ,Ef);
46 printf("\n The minimum value of excitation using eq
47 .(8.16) = %0.0f V " ,Ef816);
48 printf("\n The minimum value of excitation using eq
49 .(8.21) = %0.0f V " ,Ef821);
50 printf("\n Power angle = %0.0f deg " ,delta2);

```

Scilab code Exa 8.3 Determine System active power and Power factor of the synchronous motor and System power factor and Percent change in synchronous field current and Power angle of the synchronous motor

```

1 // Example 8.3
2 // Determine (a) System active power (b) Power
3 // factor of the synchronous motor
4 // (c) System power factor (d) Percent change in
5 // synchronous field current
6 // required to adjust the system power factor to

```

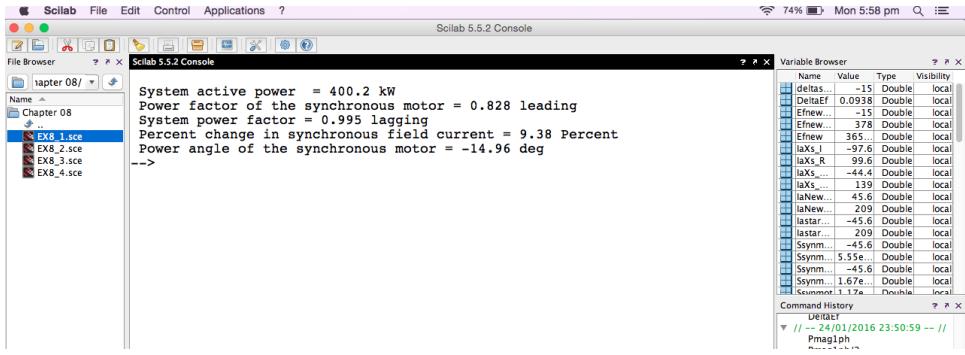


Figure 8.3: Determine System active power and Power factor of the synchronous motor and System power factor and Percent change in synchronous field current and Power angle of the synchronous motor

```

    unity (e) Power angle of the
5 // synchronous motor for the conditions in (d)
6 // Page No. 324
7
8 clc;
9 clear;
10 close;
11
12 // Given data
13
14 Php=400;                                // Power in hp
15 eta=0.958;                               // Efficiency
16 Pheater=50000;                           // Resistance heater
17 power
18 Vs=300;                                  // Synchronous motor
19 voltage
20 eta2=0.96;                               // Synchronous motor
21 efficiency
22 Xs=0.667;                               // Synchronous reactnace
23 VT=460;                                   // 3-Phase supply
24 voltage
25 delta=-16.4;                            // Power angle
26
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```

23 // (a) System active power
24 Pindmot=Php*0.75*746/(eta); // Motor operating at
      three quarter rated load
25 Psynmot=Vs*0.5*746/(eta2); // Synchronous motor
      power
26 Psys=Pindmot+Pheater+Psynmot;
27 Psysk=Psys/1000;
28
29 // (b) Power factor of the synchronous motor
30 Pin=Psynmot; // Power input
31 Vtph=VT/sqrt(3); // Voltage per phase
32 Ef=-(Pin*Xs)/(3*Vtph*sind(delta));
33 // Complex to Polar form...
34
35 Ef_Mag=Ef; // Magnitude part
36 Ef_Ang=delta; // Angle part
37 Vtph_Mag=Vtph;
38 Vtph_Ang=0;
39 ///////////
40 N01=Ef_Mag+%i*Ef_Ang; // Ef in polar form
41 N02=Vtph_Mag+%i*Vtph_Ang; // Vt in polar for
42
43 N01_R=Ef_Mag*cos(-Ef_Ang*%pi/180); // Real part of
      complex number Ef
44 N01_I=Ef_Mag*sin(Ef_Ang*%pi/180); //Imaginary part
      of complex number Ef
45
46 N02_R=Vtph_Mag*cos(-Vtph_Ang*%pi/180); // Real part
      of complex number Vt
47 N02_I=Vtph_Mag*sin(Vtph_Ang*%pi/180); //Imaginary
      part of complex number Vt
48
49 FinalNo_R=N01_R-N02_R;
50 FinalNo_I=N01_I-N02_I;
51 FinNum=FinalNo_R+%i*FinalNo_I;
52 // Complex to Polar form...
53
54 FN_M=sqrt(real(FinNum)^2+imag(FinNum)^2); //

```

```

    Magnitude part
55 FN_A = atan(imag(FinNum),real(FinNum))*180/%pi; // 
        Angle part
56
57 Ia_Mag=FN_M/Xs;           // Magnitude of Ia
58 Ia_Ang=FN_A-(-90);       // Angle of Ia
59 Theta=0-Ia_Ang;
60 FP=cosd(Theta);          // Power factor
61
62
63 // (c) System power factor
64 ThetaIndMot=acosd(0.891); // Induction motor
        power factor
65 Thetaheat=acosd(1);       // Heater power factor
66 ThetaSyncMot=-34.06;      // Synchronous motor
        power factor
67 Qindmot=tand(27)*Pindmot;
68 Qsynmot=tand(ThetaSyncMot)*Psynmot;
69 Qsys=Qindmot+Qsynmot;
70 Ssys=Psys+%i*Qsys;       // System variable in
        complex form
71
72 // Complex to Polar form...
73
74 Ssys_Mag=sqrt(real(Ssys)^2+imag(Ssys)^2);           //
        Magnitude part
75 Ssys_Ang = atan(imag(Ssys),real(Ssys))*180/%pi;     //
        Angle part
76
77 FPsyst=cosd(Ssys_Ang);          // 
        System power factor
78
79 // (d) Percent change in synchronous field current
        required to adjust the
80 // system power factor to unity
81
82 Ssynmot=Psynmot-(%i*(-Qsynmot+Qsys)); // 
        Synchronous motor system

```

```

83
84 // Complex to Polar form...
85
86 Ssynmot_Mag=sqrt(real(Ssynmot)^2+imag(Ssynmot)^2);
     // Magnitude part
87 Ssynmot_Ang=atan(imag(Ssynmot),real(Ssynmot))*180/
     %pi; // Angle part
88
89 Ssynmot1ph_Mag=Ssynmot_Mag/3;                      // For
     single phase magnitude
90 Ssynmot1ph_Ang=Ssynmot_Ang;                        // For
     single phase angle
91
92 Iastar_Mag=Ssynmot1ph_Mag/Vtph;                  // Current
     magnitude
93 Iastar_Ang=Ssynmot1ph_Ang-0;                     // Current
     angle
94
95 IaNew_Mag=Iastar_Mag;
96 IaNew_Ang=-Iastar_Ang;
97
98 IaXs_Mag=IaNew_Mag*Xs;
99 IaXs_Ang=IaNew_Ang-90;
100
101 // Convert these number into complex and then
     perform addition
102 // Polar to Complex form
103
104 // Y=29.416<-62.3043 //Polar form number
105 IaXs_R=IaXs_Mag*cos(-IaXs_Ang*%pi/180); // Real
     part of complex number
106 IaXs_I=IaXs_Mag*sin(IaXs_Ang*%pi/180); // Imaginary part of complex number
107 Efnew=Vtph+IaXs_R+%i*IaXs_I;
108 // Complex to Polar form...
109
110 Efnew_Mag=sqrt(real(Efnew)^2+imag(Efnew)^2);    //
     Magnitude part

```

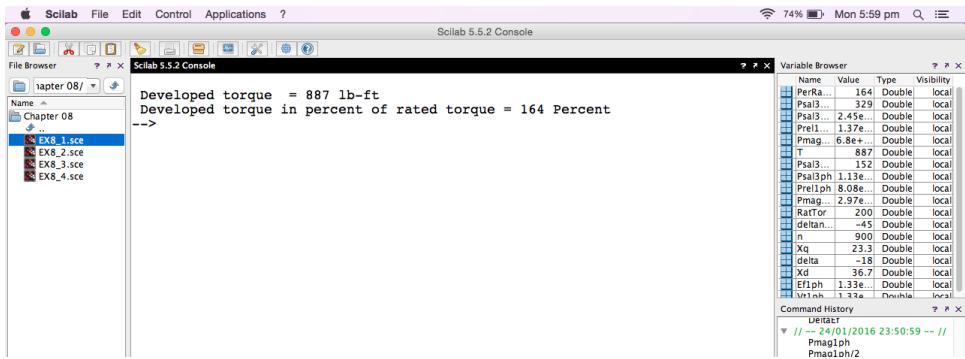


Figure 8.4: Determine Developed torque and Developed torque in percent of rated torque

```

111 Efnew_Ang=atan(imag(Efnew),real(Efnew))*180/%pi; //  
Angle part  
112  
113 DeltaEf=(Efnew_Mag-Ef)/Ef;  
114  
115 // (e) Power angle of the synchronous motor  
116 deltasynmot=Efnew_Ang;  
117  
118 // Display result on command window  
119 printf("\n System active power = %0.1f kW ",Psysk);  
120 printf("\n Power factor of the synchronous motor =  
%0.3f leading ",FP);  
121 printf("\n System power factor = %0.3f lagging ",  
FPsys);  
122 printf("\n Percent change in synchronous field  
current = %0.2f Percent ",DeltaEf*100);  
123 printf("\n Power angle of the synchronous motor = %0  
.2f deg ",deltasynmot);

```

Scilab code Exa 8.4 Determine Developed torque and Developed torque in percent of rated torque

```

1 // Example 8.4
2 // Determine (a) Developed torque if the field
   current is adjusted so that the
3 // excitation voltage is equal to two times the
   applied stator voltage , and the
4 // power angle is -18 degrees (b) Developed torque
   in percent of rated torque ,
5 // if the load is increased until maximum reluctance
   torque occurs .
6 // Page No. 328
7
8 clc;
9 clear;
10 close;
11
12 // Given data
13 Vt1ph=2300/sqrt(3);           // Applied voltage/phase
14 Ef1ph=2300/sqrt(3);           // Excitation voltage/
   phase
15 Xd=36.66;                   // Direct axis reactance
   /phase
16 delta=-18;                  // Power angle
17 Xq=23.33;                   // Quadrature-axis
   reactance/phase
18 n=900;                      // Speed of motor
19 deltanew=-45;
20 RatTor=200;                  // Rated torque of motor
21 // (a) Developed torque
22 Pmag1ph=-((Vt1ph*2*Ef1ph)/Xd)*sind(delta); // Power
23 Prel1ph=-Vt1ph^2*((Xd-Xq)/(2*Xd*Xq))*sind(2*
   delta); // Reluctance power
24 Psal3ph=3*(Pmag1ph+Prel1ph); // Salient power of
   motor
25 Psal3phHP=Psal3ph/746;
26 T=(5252*Psal3phHP)/n;       // Developed torque

```

```

27
28 // (b) Developed torque in percent of rated torque
29 // The reluctance torque has its maximum value at
   delta= -45 degrees
30 Pmag1phnew=-(Vt1ph*2*Ef1ph)/Xd)*sind(deltanew); // Power
31 Prel1phnew=-Vt1ph^2*( (Xd-Xq) / (2*Xd*Xq)) *sind(2*
   deltanew); // Reluctance power
32 Psal3phnew=3*(Pmag1phnew+Prel1phnew); // Salient
   power of motor
33 Psal3phHPnew=Psal3phnew/746;
34 PerRatTorq=Psal3phHPnew*100/RatTor;
35
36 // Display result on command window
37 printf("\n Developed torque = %0.0f lb-ft ",T);
38 printf("\n Developed torque in percent of rated
   torque = %0.0f Percent ",PerRatTorq);

```

Chapter 9

Synchronous Generators

Scilab code Exa 9.1 Determine Turbine torque supplied to the alternator and Excitation voltage and Active and reactive components of apparent power and Power factor and Excitation voltage

```
1 // Example 9.1
2 // Determine (a) Turbine torque supplied to the
   alternator (b) Excitation
3 // voltage (c) Active and reactive components of
   apparent power (d) Power
4 // factor (e) Neglecting saturation effects ,
   excitation voltage if the field
5 // current is reduced to 85% of its voltage in (a) (f)
   // Turbine speed.
6 // Page No. 342
7
8 clc;
9 clear;
10 close;
11
12 // Given data
13 hp=112000;           // Power input
```

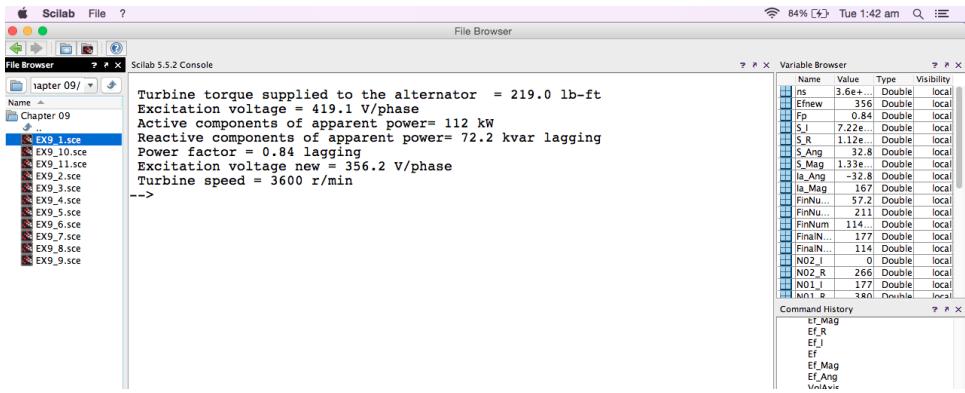


Figure 9.1: Determine Turbine torque supplied to the alternator and Excitation voltage and Active and reactive components of apparent power and Power factor and Excitation voltage

```

14 n=746*3600;                                // Speed
15 VT=460;                                     // 3-Phase supply
     voltage
16 Pout=112000;                                // Power
17 Xs=1.26;                                     // Synchronous reactance
18 delta=25;                                    // Power angle
19 eta=0.85;                                    // Percent reduction
     factor
20 P=2;                                         // Number of poles
21 f=60;                                        // Frequency
22
23 // (a) Turbine torque supplied to the alternator
24 T=(hp*5252)/n;
25
26 // (b) Excitation voltage
27 Vt=VT/sqrt(3);                               // Voltage/phase
28 Ef=(Pout*Xs)/(3*Vt*sind(delta));
29
30 // (c) Active and reactive components of apparent
     power
31 // Vt=Ef-Ia*j*Xs
32 // Solving for Vt-Ef

```

```

33 Vt_Mag=Vt;
34 Vt_Ang=0;
35 Ef_Mag=Ef;
36 Ef_Ang=delta;
37 //
38 N01=Ef_Mag+%i*Ef_Ang;           // Ef in polar form
39 N02=Vt_Mag+%i*Vt_Ang;           // Vt in polar for
40
41 N01_R=Ef_Mag*cos(-Ef_Ang*%pi/180); // Real part of
   complex number Ef
42 N01_I=Ef_Mag*sin(Ef_Ang*%pi/180); //Imaginary part
   of complex number Ef
43
44 N02_R=Vt_Mag*cos(-Vt_Ang*%pi/180); // Real part of
   complex number Vt
45 N02_I=Vt_Mag*sin(Vt_Ang*%pi/180); //Imaginary part
   of complex number Vt
46
47 FinalNo_R=N01_R-N02_R;
48 FinalNo_I=N01_I-N02_I;
49 FinNum=FinalNo_R+%i*FinalNo_I;
50
51 // Now FinNum/Xs in polar form
52 FinNum_Mag=sqrt(real(FinNum)^2+imag(FinNum)^2);
   // Magnitude part
53 FinNum_Ang = atan(imag(FinNum),real(FinNum))*180/%pi
   ; // Angle part
54 Ia_Mag=FinNum_Mag/Xs;
55 Ia_Ang=FinNum_Ang-90;
56
57 // Computation of S=3*Vt*Ia*
58 S_Mag=3*Vt_Mag*Ia_Mag;
59 S_Ang=Vt_Ang+-Ia_Ang;
60
61 // Polar to complex form
62 S_R=S_Mag*cos(-S_Ang*%pi/180); // Real part of
   complex number S
63 S_I=S_Mag*sin(S_Ang*%pi/180); // Imaginary part of

```

```

        complex number S
64
65 // (d) Power factor
66 Fp=cosd(Ia_Ang);
67
68 // (e) Excitation voltage
69 Efnew=eta*Ef_Mag;
70
71 // (f) Turbine speed
72 ns=120*f/P;
73
74 // Display result on command window
75 printf("\n Turbine torque supplied to the alternator
           = %0.1f lb-ft ",T);
76 printf("\n Excitation voltage = %0.1f V/phase ",Ef);
77 printf("\n Active components of apparent power= %0.0
           f kW ",S_R/1000);
78 printf("\n Reactive components of apparent power= %0
           .1f kvar lagging ",S_I/1000);
79 printf("\n Power factor = %0.2f lagging ",Fp);
80 printf("\n Excitation voltage new = %0.1f V/phase ",
           Efnew);
81 printf("\n Turbine speed = %0.0f r/min ",ns);

```

Scilab code Exa 9.2 Determine Speed regulation and Governor drop

```

1 // Example 9.2
2 // Determine (a) Speed regulation (b) Governor drop
3 // Page 351
4
5 clc;
6 clear;
7 close;

```

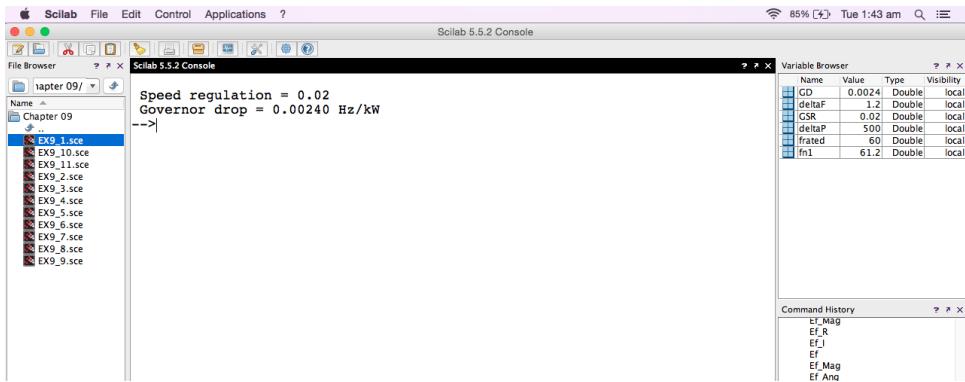


Figure 9.2: Determine Speed regulation and Governor drop

```

8
9 // Given data
10 fn1=61.2;                                // No-load frequency
11 frated=60;                                 // Rated frequency
12 deltaP=500;                               // Governor rated power
13 // (a) Speed regulation
14 GSR=(fn1-frated)/frated;
15
16 // (b) Governor drop
17 deltaF=(fn1-frated);                      // Frequency difference
18 GD=deltaF/deltaP;
19
20 // Display result on command window
21 printf("\n Speed regulation = %0.2f ",GSR);
22 printf("\n Governor drop = %0.5f Hz/kW ",GD);

```

Scilab code Exa 9.3 Determine Frequency of generator A and Frequency of generator B and Frequency of bus

```
1 // Example 9.3
```

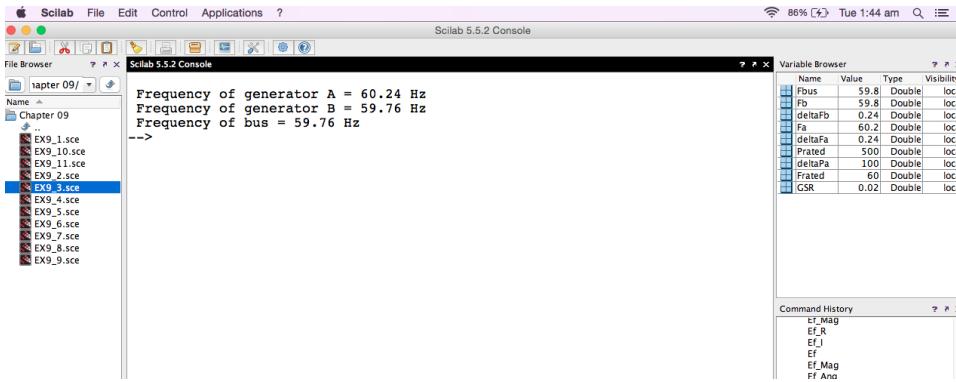


Figure 9.3: Determine Frequency of generator A and Frequency of generator B and Frequency of bus

```

2 // Determine (a) Frequency of generator A (b)
    Frequency of generator B
3 // (c) Frequency of bus
4 // Page 358
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 GSR=0.020;                                // Governor speed
    regulation
12 Frated=60;                                 // Rated frequency
13 deltaPa=100;                               // Change in load
    (200-100 =100 KW)
14 Prated=500;                                // Rated power of both
    generators
15
16
17 // (a) Frequency of generator A
18 deltaFa=(GSR*Frated*deltaPa)/Prated; // Change in
    frequency due to change in load
19 Fa=Frated+deltaFa;                         // Frequency of
    generator A

```

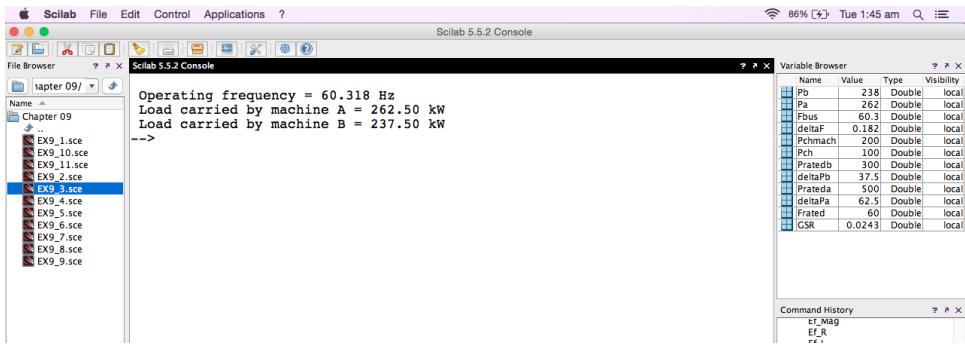


Figure 9.4: Determine Operating frequency and Load carried by each machine

```

20
21 // (b) Frequency of generator B
22 deltaFb=0.24;                                // Since both
23 machines are identical
24 Fb=Frated-deltaFb;
25 // (c) Frequency of bus
26 Fbus=Fb;                                     // Bus
27 frequency is frequency of generator B
28 // Display result on command window
29 printf("\n Frequency of generator A = %0.2f Hz ",Fa)
30 ;
31 printf("\n Frequency of generator B = %0.2f Hz ",Fb)
32 ;
33 printf("\n Frequency of bus = %0.2f Hz ",Fbus);

```

Scilab code Exa 9.4 Determine Operating frequency and Load carried by each machine

```

1 // Example 9.4
2 // Determine (a) Operating frequency (b) Load
   carried by each machine
3 // Page 359
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 GSR=0.0243;                                // Governor speed
11 regulation
11 Frated=60;                                  // Rated frequency
12 deltaPa=500;                                // Change in load for
   alternator A
13 Prateda=500;                                // Rated power of
   alternator A
14 deltaPb=400;                                // Change in load for
   alternator B
15 Pratedb=300;                                // Rated power of
   alternator B
16 Pch=100;                                    // Change in power
   (500-400=100 KW)
17 Pchmach=200;                                // Power difference
   (500-300=200 KW)
18
19 // (a) Operating frequency
20 // From the curve in figure 9.17
21 // GSR*Frated/Prated=deltaP/deltaP
22
23 deltaF=(deltaPa-deltaPb)/548.697;      // Change in
   frequency
24 Fbus=60.5-deltaF;
25
26
27 // (b) Load carried by each machine
28 deltaPa=(deltaF*Prateda)/(GSR*Frated); // Change in
   power for machine A

```

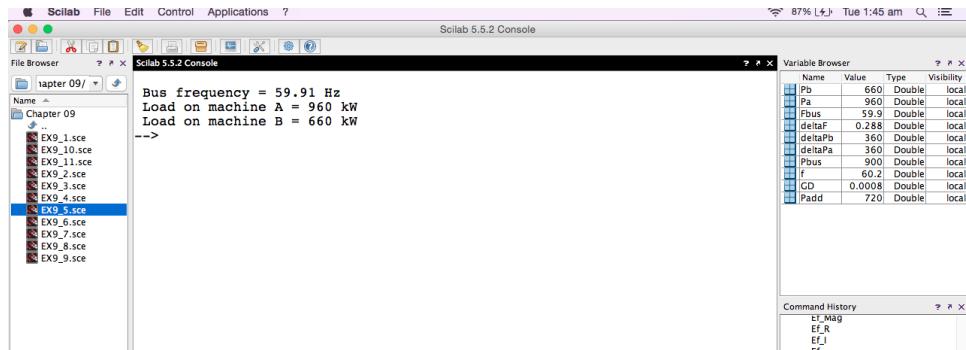


Figure 9.5: Determine Bus frequency and Load on each machine

```

29 deltaPb=Pch-deltaPa; // Change in
                         power for machine B
30 Pa=Pchmach+deltaPa;
31 Pb=Pchmach+deltaPb;
32
33 // Display result on command window
34 printf("\n Operating frequency = %0.3f Hz ",Fbus);
35 printf("\n Load carried by machine A = %0.2f kW",Pa)
      ;
36 printf("\n Load carried by machine B = %0.2f kW",Pb)
      ;

```

Scilab code Exa 9.5 Determine Bus frequency and Load on each machine

```

1 // Example 9.5
2 // Determine (a) Bus frequency (b) Load on each
   machine
3 // Page 360
4
5 clc;
6 clear;

```

```

7 close;
8
9 // Given data
10 Padd=720;                                // Additional load
11 GD=0.0008;                                 // Governor droop
12 f=60.2;                                    // Frequency of machine
13 Pbus=900;                                   // Bus load
14
15 // (a) Bus frequency
16 deltaPa=Padd/2;
17 deltaPb=deltaPa;                          // Since both machines
18 have identical governor drops
19 deltaF=GD*deltaPa;                      // Change in frequency
20 Fbus=f-deltaF;
21
22 // (b) Load on each machine
23 Pa=(2/3)*Pbus+deltaPa;                  // Load on machine A
24 Pb=(1/3)*Pbus+deltaPb;                  // Load on machine B
25
26 printf("\n Bus frequency = %0.2f Hz ",Fbus);
27 printf("\n Load on machine A = %0.0f kW",Pa);
28 printf("\n Load on machine B = %0.0f kW",Pb);

```

Scilab code Exa 9.6 Determine System kilowatts and System frequency and kilowatt loads carried by each machine

```

1 // Example 9.6
2 // Determine (a) System kilowatts (b) System
3 // frequency (c) kilowatt loads
4 // carried by each machine
5 // Page 361

```

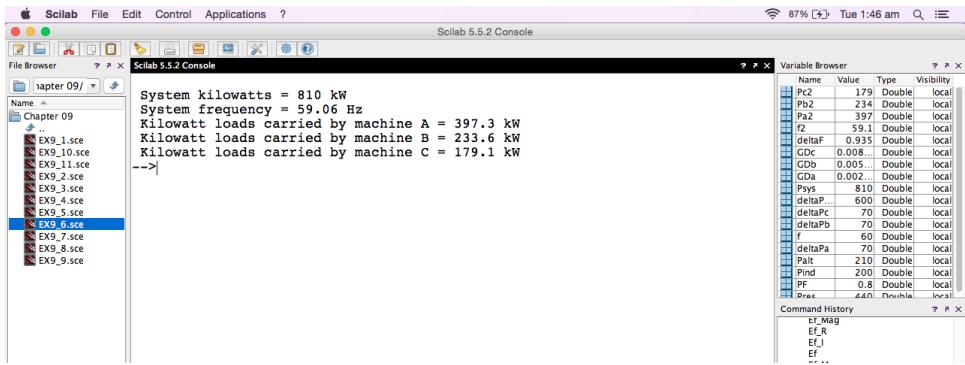


Figure 9.6: Determine System kilowatts and System frequency and kilowatt loads carried by each machine

```

5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 Pres=440;                                // Resistive load
12 PF=0.8;                                    // Power factor
13 Pind=200;                                  // Induction motor
14 Palt=210;                                   // Alternator bus load
15 deltaPa=70;                                 // Change in load for
16 machine A
17 deltaPb=70;                                 // Frequency
18 machine B
19 deltaPc=70;                                 // Change in load for
20 machine C
21 // (a) System kilowatts
22 deltaPbus=Pres+PF*Pind;                   // Increase in bus load
23 Psys=Palt+deltaPbus;
24 // (b) System frequency

```

```

25 GDa=(60.2-f)/deltaPa;           // Governor droop for
        machine A
26 GDb=(60.4-f)/deltaPb;           // Governor droop for
        machine B
27 GDC=(60.6-f)/deltaPc;           // Governor droop for
        machine C
28 // From the figure 9.18(b)
29 deltaF=600/(350+175+116.6667) ;
30 f2=f-deltaF;
31
32 // (c) Kilowatt loads carried by each machine
33 Pa2=deltaPa+350*deltaF;
34 Pb2=deltaPb+175*deltaF;
35 Pc2=deltaPc+116.6667*deltaF;
36
37 // Display result on command window
38 printf("\n System kilowatts = %0.0f kW ",Psys);
39 printf("\n System frequency = %0.2f Hz",f2);
40 printf("\n Kilowatt loads carried by machine A = %0
        .1f kW",Pa2);
41 printf("\n Kilowatt loads carried by machine B = %0
        .1f kW",Pb2);
42 printf("\n Kilowatt loads carried by machine C = %0
        .1f kW",Pc2);

```

Scilab code Exa 9.7 Determine Active and reactive components of the bus load and Determine the reactive power supplied by each machine

```

1 // Example 9.7
2 // Determine (a) Active and reactive components of
   the bus load (b) If the
3 // power factor of generator A is 0.94 lagging ,
   determine the reactive power

```

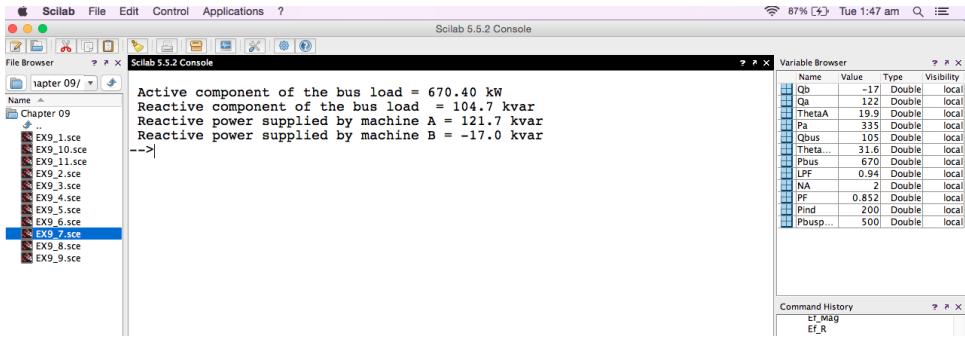


Figure 9.7: Determine Active and reactive components of the bus load and Determine the reactive power supplied by each machine

```

4 // supplied by each machine.
5 // Page 366
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 Pbuspower=500;           // Power supplied
13 Pind=200;                // Induction motor power
14 PF=0.852;                // Percent power factor
15 NA=2;                    // Number of alternators
16 LPF=0.94;                // Lagging power factor
17
18 // (a) Active and reactive components of the bus
19 // load
20 Pbus=Pbuspower+Pind*PF;   // Active component of
21 // the bus load
22 ThetaMot=acosd(PF);       // Power angle of motor
23 Qbus=Pind*sind(ThetaMot); // Reactive component
24 // the bus load
25
26 // (b) Reactive power supplied by each machine
27 PA=Pbus/NA;              // Alternator A power
28 ThetaA=acosd(LPF);        // Alternator A angle

```

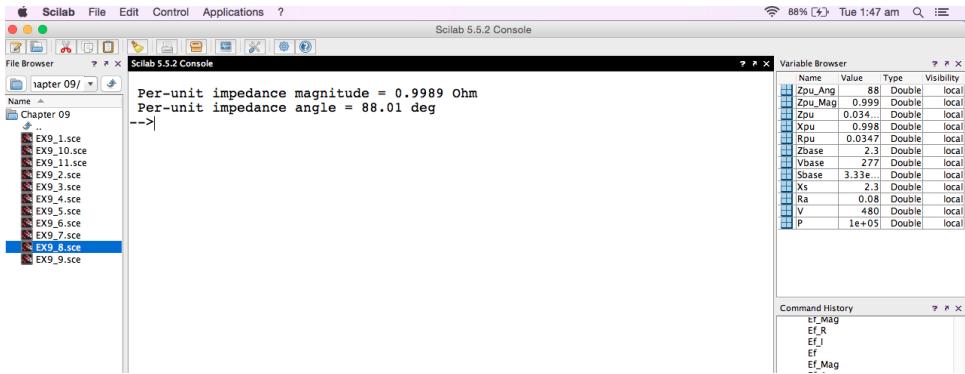


Figure 9.8: Computation of per unit impedance of a generator

```

26 Qa=tand(ThetaA)*Pa;           // Reactive power
      supplied by machine A
27 Qb=Qbus-Qa;                 // Reactive power
      supplied by machine B
28
29
30 // Display result on command window
31 printf("\n Active component of the bus load = %0.2f
      kW ",Pbus);
32 printf("\n Reactive component of the bus load = %0
      .1f kvar",Qbus);
33 printf("\n Reactive power supplied by machine A = %0
      .1f kvar",Qa);
34 printf("\n Reactive power supplied by machine B = %0
      .1f kvar",Qb);

```

Scilab code Exa 9.8 Computation of per unit impedance of a generator

```

1 // Example 9.8
2 // Computation of per-unit impedance of a generator
3 // Page 368

```

```

4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 P=100000; // Power of synchronous
   generator
11 V=480; // Voltage of
   synchronous generator
12 Ra=0.0800; // Resistive component
13 Xs=2.3; // Reactive component
14
15 // Computation of per-unit impedance of a generator
16 Sbase=P/3; // Rated apparent power
   per phase
17 Vbase=V/sqrt(3); // Rated voltage per
   phase
18 Zbase=Vbase^2/Sbase; // Rated impedance
19 Rpu=Ra/Zbase; // Per unit resistance
20 Xpu=Xs/Zbase; // Per unit reactance
21
22 Zpu=Rpu+%i*Xpu; // Per unit impedance
23
24 // Complex to Polar form...
25 Zpu_Mag=sqrt(real(Zpu)^2+imag(Zpu)^2); // // Magnitude part
26 Zpu_Ang = atan(imag(Zpu),real(Zpu))*180/%pi; // Angle part
27
28 // Display result on command window
29 printf("\n Per-unit impedance magnitude = %0.4f Ohm
   ",Zpu_Mag);
30 printf("\n Per-unit impedance angle = %0.2f deg ", Zpu_Ang);

```

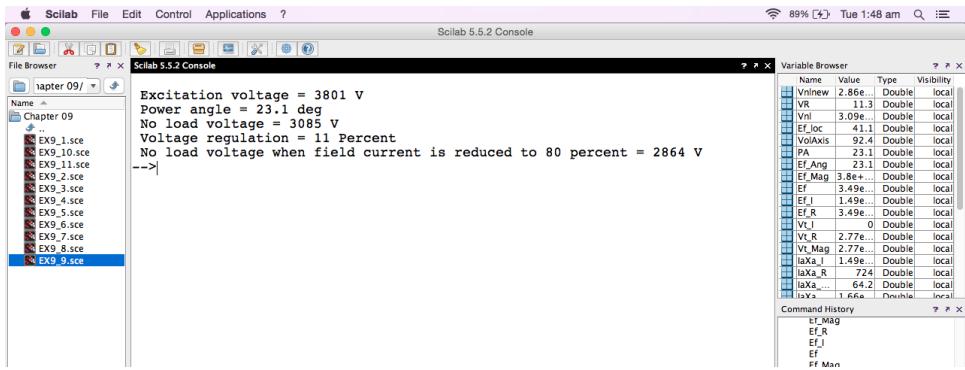


Figure 9.9: Determine Excitation voltage and Power angle and No load voltage and Voltage regulation and No load voltage if the field current is reduced to 80 percent

Scilab code Exa 9.9 Determine Excitation voltage and Power angle and No load voltage and Voltage regulation and No load voltage if the field current is reduced to 80 percent

```

1 // Example 9.9
2 // Determine (a) Excitation voltage (b) Power angle
   (c) No load voltage ,
3 // assuming the field current is not changed (d)
   Voltage regulation (e) No load
4 // voltage if the field current is reduced to 80% of
   its value at rated load .
5 // Page 369
6
7 clc;
8 clear;
9 close;
10
11 // Given data

```

```

12 V=4800; // Voltage of
           synchronous generator
13 PF=0.900; // Lagging power factor
14 S_Mag=1000000/3;
15 Xa_Mag=13.80; // Synchronous reactance
16 Xa_Ang=90;
17 Vt_Ang=0;
18
19 // (a) Excitation voltage
20 Vt=V/sqrt(3);
21 Theta=acosd(PF); // Angle
22 Ia_Magstar=S_Mag/Vt; // Magnitude of
                         current
23 Ia_Angstar=Theta-0; // Angle of current
24 Ia_Mag=Ia_Magstar;
25 Ia_Ang=-Ia_Angstar;
26
27 // Ef=Vt+Ia*j*Xa
28 // First compute Ia*Xa
29 IaXa_Mag=Ia_Mag*Xa_Mag;
30 IaXa_Ang=Ia_Ang+Xa_Ang;
31 // Polar to Complex form for IaXa
32 IaXa_R=IaXa_Mag*cos(-IaXa_Ang*pi/180); // Real part
                                               of complex number
33 IaXa_I=IaXa_Mag*sin(IaXa_Ang*pi/180); // Imaginary
                                               part of complex number
34 // Vt term in polar form
35 Vt_Mag=Vt;
36 Vt_Ang=Vt_Ang;
37 // Polar to Complex form for Vt
38 Vt_R=Vt_Mag*cos(-Vt_Ang*pi/180); // Real part
                                               of complex number
39 Vt_I=Vt_Mag*sin(Vt_Ang*pi/180); // Imaginary
                                               part of complex number
40 // Ef in complex form
41 Ef_R=IaXa_R+Vt_R;
42 Ef_I=IaXa_I+Vt_I;
43 Ef=Ef_R+%i*Ef_I;

```

```

44 // Complex to Polar form for Ef
45 Ef_Mag=sqrt(real(Ef)^2+imag(Ef)^2);           // 
        Magnitude part
46 Ef_Ang= atan(imag(Ef),real(Ef))*180/%pi;     // Angle
        part
47
48 // (b) Power angle
49 PA=Ef_Ang;
50
51 // (c) No load voltage , assuming the field current
        is not changed
52 // From figure 9.23 (b)
53 VolAxis=Vt_Mag/30;                // The scale at the given
        voltage axis
54 Ef_loc=Ef_Mag/VolAxis;          // Location of Ef voltage
55 Vnl=33.4*VolAxis;              // No load voltage
56
57 // (d) Voltage regulation
58 VR=(Vnl-Vt)/Vt*100;
59
60 // (e) No load voltage if the field current is
        reduced to 80%
61 Vnlnew=31*VolAxis;
62
63 // Display result on command window
64 printf("\n Excitation voltage = %0.0f V ",Ef_Mag);
65 printf("\n Power angle = %0.1f deg ",PA);
66 printf("\n No load voltage = %0.0f V ",Vnl);
67 printf("\n Voltage regulation = %0.0f Percent ",VR);
68 printf("\n No load voltage when field current is
        reduced to 80 percent = %0.0f V ",Vnlnew);

```

Scilab code Exa 9.10 Determine Excitation voltage and Power angle and

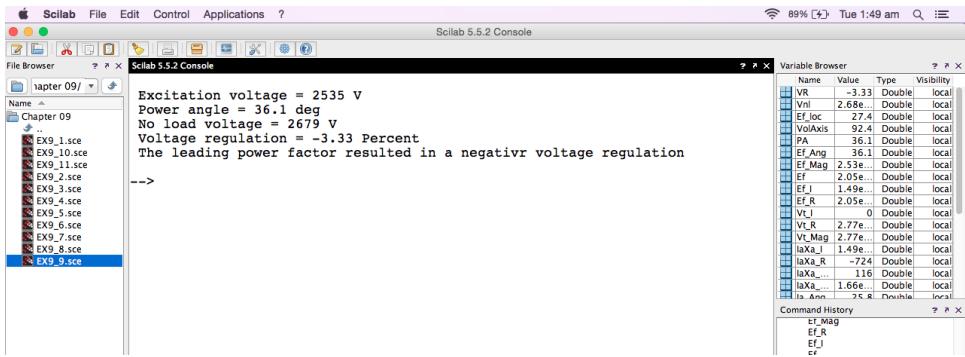


Figure 9.10: Determine Excitation voltage and Power angle and No load voltage and Voltage regulation and No load voltage if the field current is reduced to 80 percent

No load voltage and Voltage regulation and No load voltage if the field current is reduced to 80 percent

```

1 // Example 9.10
2 // Repeat the example 9.9 assuming 90 % leading
   power factor
3 // Determine (a) Excitation voltage (b) Power angle
   (c) No load voltage ,
4 // assuming the field current is not changed (d)
   Voltage regulation (e) No load
5 // voltage if the field current is reduced to 80% of
   its value at rated load.
6 // Page 372
7
8 clc;
9 clear;
10 close;
11
12 // Given data
13 V=4800;                                // Voltage of
   synchronous generator
14 PF=0.900;                               // Lagging power factor
15 S_Mag=1000000/3;
```

```

16 Xa_Mag=13.80;                                // Synchronous reactance
17 Xa_Ang=90;
18 Vt_Ang=0;
19
20 // (a) Excitation voltage
21 Vt=V/sqrt(3);
22 Theta=acosd(PF);                            // Angle
23 Ia_Magstar=S_Mag/Vt;                        // Magnitude of
                                               current
24 Ia_Angstar=Theta-0;                          // Angle of current
25 Ia_Mag=Ia_Magstar;
26 Ia_Ang=Ia_Angstar;
27
28 // Ef=Vt+Ia*j*Xa
29 // First compute Ia*Xa
30 IaXa_Mag=Ia_Mag*Xa_Mag;
31 IaXa_Ang=Ia_Ang+Xa_Ang;
32 // Polar to Complex form for IaXa
33 IaXa_R=IaXa_Mag*cos(-IaXa_Ang*pi/180); // Real part
                                               of complex number
34 IaXa_I=IaXa_Mag*sin(IaXa_Ang*pi/180); // Imaginary
                                               part of complex number
35 // Vt term in polar form
36 Vt_Mag=Vt;
37 Vt_Ang=Vt_Ang;
38 // Polar to Complex form for Vt
39 Vt_R=Vt_Mag*cos(-Vt_Ang*pi/180);          // Real part
                                               of complex number
40 Vt_I=Vt_Mag*sin(Vt_Ang*pi/180);           // Imaginary
                                               part of complex number
41 // Ef in complex form
42 Ef_R=IaXa_R+Vt_R;
43 Ef_I=IaXa_I+Vt_I;
44 Ef=Ef_R+%i*Ef_I;
45 // Complex to Polar form for Ef
46 Ef_Mag=sqrt(real(Ef)^2+imag(Ef)^2);        //
                                               Magnitude part
47 Ef_Ang= atan(imag(Ef),real(Ef))*180/pi;    // Angle

```

```

        p a r t
48
49 // (b) Power angle
50 PA=Ef_Ang;
51
52 // (c) No load voltage , assuming the field current
      is not changed
53 // From figure 9.23 (b)
54 VolAxis=Vt_Mag/30;           // The scale at the given
      voltage axis
55 Ef_loc=Ef_Mag/VolAxis;       // Location of Ef voltage
56 Vnl=29*VolAxis;             // No load voltage
57
58 // (d) Voltage regulation
59 VR=(Vnl-Vt)/Vt*100;
60
61
62 // Display result on command window
63 printf("\n Excitation voltage = %0.0f V ",Ef_Mag);
64 printf("\n Power angle = %0.1f deg ",PA);
65 printf("\n No load voltage = %0.0f V ",Vnl);
66 printf("\n Voltage regulation = %0.2f Percent ",VR);
67 disp('The leading power factor resulted in a
      negativr voltage regulation')

```

Scilab code Exa 9.11 Determine Equivalent armature resistance and Synchronous reactance and Short circuit ratio

```

1 // Example 9.11
2 // Determine (a) Equivalent armature resistance (b)
      Synchronous reactance
3 // (c) Short-circuit ratio
4 // Page 377

```

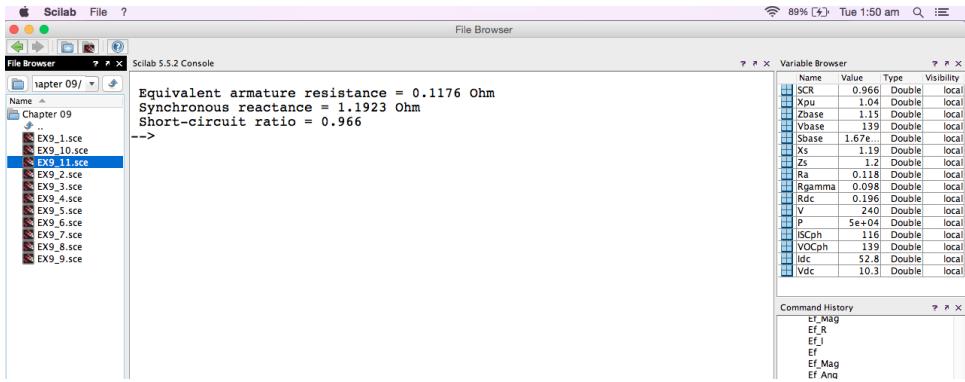


Figure 9.11: Determine Equivalent armature resistance and Synchronous reactance and Short circuit ratio

```

5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 Vdc=10.35; // DC voltage
12 Idc=52.80; // DC current
13 VOCph=240/sqrt(3); // Open-circuit phase
   voltage
14 ISCph=115.65; // Short-circuit phase
   current
15 P=50000;
16 V=240; // Supply voltage
17
18 // (a) Equivalent armature resistance
19 Rdc=Vdc/Idc; // DC resistance
20 Rgamma=Rdc/2;
21 Ra=1.2*Rgamma; // Armature resistance
22
23 // (b) Synchronous reactance
24 Zs= VOCph/ISCph; // Synchronous impedance/
   phase
25 Xs=sqrt(Zs^2-Ra^2);

```

```

26
27 // (c) Short-circuit ratio
28 Sbase=P/3;           // Power/phase
29 Vbase=V/sqrt(3);    // Voltage/phase
30 Zbase=Vbase^2/Sbase;
31 Xpu=Xs/Zbase;      // Per unit synchronous
                      reactance
32 SCR=1/Xpu;          // Short-circuit ratio
33
34
35 // Display result on command window
36 printf("\n Equivalent armature resistance = %0.4f
          Ohm ",Ra);
37 printf("\n Synchronous reactance = %0.4f Ohm ",Xs);
38 printf("\n Short-circuit ratio = %0.3f ",SCR);

```

Chapter 10

Principles of Direct Current Machines

Scilab code Exa 10.1 Computation of Induced emf and Frequency of the rectangular voltage wave in the armature winding

```
1 // Example 10.1
2 // Computation of (a) Induced emf (b) Frequency of
   the rectangular voltage
3 // wave in the armature winding
4 // Page No. 394
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 E1=136.8;           // Generated emf
12 P=6;                // Number of poles
13 n=1180;              // Operating speed of
   machine
14
```



Figure 10.1: Computation of Induced emf and Frequency of the rectangular voltage wave in the armature winding

```

15 // (a) Induced emf
16
17 E2=E1*0.75*2;
18
19 // (b) Frequency of the rectangular voltage wave in
   the armature winding
20
21 f=P*n*0.75/120;
22
23 //Display result on command window
24 printf("\n Induced emf = %0.1f V ",E2);
25 printf("\n Frequency of the rectangular voltage wave
   = %0.2f Hz ",f);
```

Scilab code Exa 10.2 Computation of rheostat setting required to obtain an induced emf of 290 V

```
1 // Example 10.2
```



Figure 10.2: Computation of rheostat setting required to obtain an induced emf of 290 V

```

2 // Computation of rheostat setting required to
   obtain an induced emf of 290 V
3 // Page No. 399
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 Eb=240;           // Induced emf
11 If=8.9;           // Field current
12 Rf=10.4;          // Field resistance
13
14 // Rheostat setting required to obtain an induced
   emf of 290 V
15
16 Rrheo=(Eb/If)-Rf;
17
18 // Display result on command window
19 printf("\n Rheostat setting to obtain an induced emf
   of 290 V = %0.2f ",Rrheo);

```

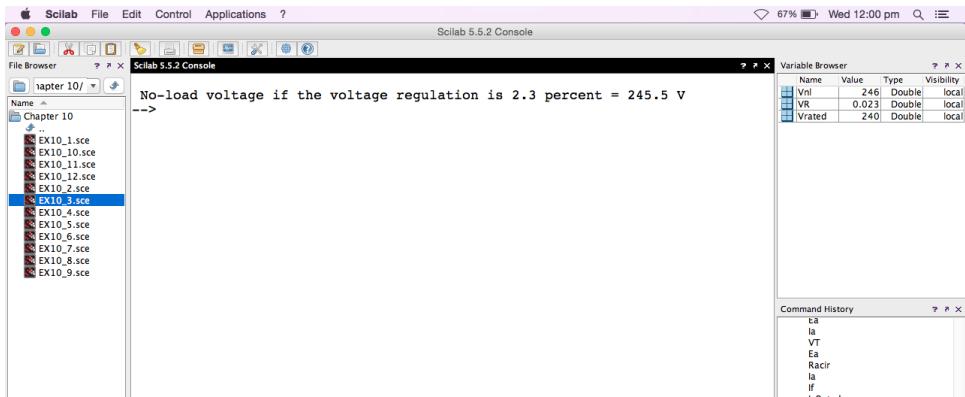


Figure 10.3: Computation of no load voltage

Scilab code Exa 10.3 Computation of no load voltage

```

1 // Example 10.3
2 // Computation of no-load voltage if the voltage
   regulation is 2.3 percent
3 // Page No. 401
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 Vrated=240;                      // Rated voltage
11 VR=0.023;                        // Voltage regulation
12
13
14 // No--load voltage if the voltage regulation is 2.3
   percent
15
16 Vnl=Vrated*(1+VR);
17

```

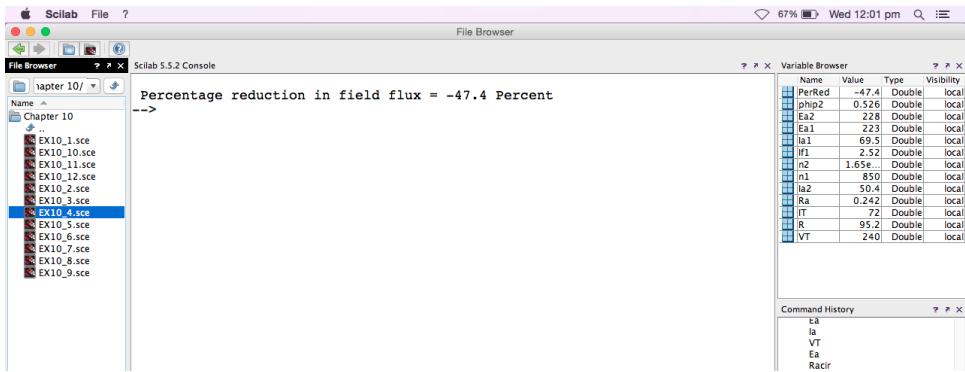


Figure 10.4: Computation of percentage reduction in field flux required to obtain a speed of 1650 rpm

```

18 // Display result on command window
19 printf("\n No-load voltage if the voltage regulation
      is 2.3 percent = %0.1f V ",Vnl);

```

Scilab code Exa 10.4 Computation of percentage reduction in field flux required to obtain a speed of 1650 rpm

```

1 // Example 10.4
2 // Computation of percentage reduction in field flux
   required to obtain a
3 // speed of 1650 r/min while drawing an armature
   current of 50.4 A.
4 // Page No. 405
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 VT=240;           // Induced emf

```



Figure 10.5: Computation of no load speed

```

12 R=95.2;                                // Shunt field resistance
13 IT=72;                                   // Total current
14 Ra=0.242;                               // Armature resistance
15 Ia2=50.4;                               // Armature current
16 n1=850;                                  // Rated speed of shunt motor
17 n2=1650;                                // Speed of armature winding
18
19
20 // Percentage reduction in field flux
21
22 If1=VT/R;                                // Field current
23 Ia1=IT-If1;                               // Armature current
24 Ea1=VT-Ia1*Ra;                            // Armature emf
25 Ea2=VT-Ia2*Ra;
26 phip2=(n1/n2)*(Ea2/Ea1);
27 PerRed=(phip2-1)*100;
28
29
30
31 // Display result on command window
32 printf("\n Percentage reduction in field flux = %0.1
        f Percent ",PerRed);

```

Scilab code Exa 10.5 Computation of no load speed

```
1 // Example 10.5
2 // Computation of no-load speed
3 // Page No. 408
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 nrated=1750; // Rated speed
11 SR=4; // Speed regulation
12
13 // No-load speed
14
15 Snl=nrated*(1+SR/100);
16
17 // Display result on command window
18 printf("\n No-load speed = %0.0 f r/min ",Snl);
```

Scilab code Exa 10.6 Computation of Induced emf

```
1 // Example 10.6
2 // Computation of Induced emf
3 // Page No. 418
4
5 clc;
6 clear;
7 close;
```

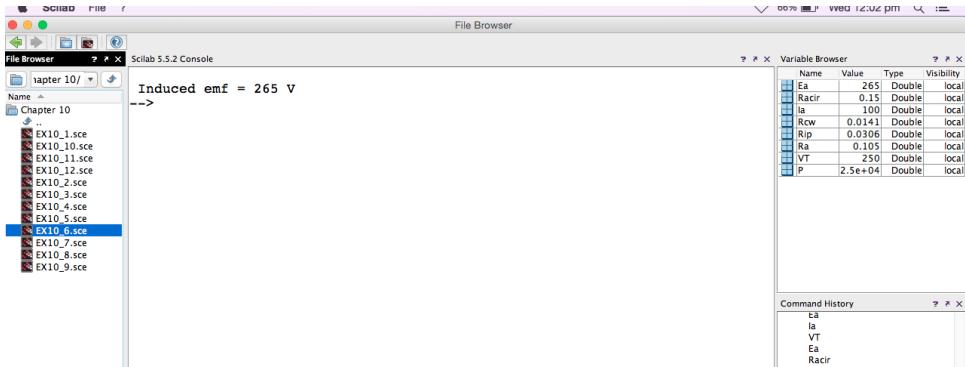


Figure 10.6: Computation of Induced emf

```

8
9 // Given data
10 P=25000; // Power of the generator
11 VT=250; // Rated voltage of the
           machine
12 Ra=0.1053; // Armature resistance
13 Rip=0.0306; // Resistance of interpolar
               winding
14 Rcw=0.0141; // Resistance of compensating
               windings
15
16
17 // Induced emf
18 Ia=P/VT; // Armature current
19 Racir=Ra+Rip+Rcw; // Resistance of armature
                      circuit
20 Ea=VT+Ia*Racir; // Induced emf
21
22
23 // Display result on command window
24 printf("\n Induced emf = %0.0f V ",Ea);

```



Figure 10.7: Computation of cemf

Scilab code Exa 10.7 Computation of cemf

```

1 // Example 10.7
2 // Computation of cemf
3 // Page No. 418
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 Rf=408.5;           // Field resistance
11 VT=500;             // Rated voltage of the
                         machine
12 IT=51.0;            // Total current
13 Ra=0.602;           // Armature resistance
14 Ripcw=0.201;         // Resistance of interpolar
                         winding and compensating windings
15
16 // Induced emf
17 If=VT/Rf;           // Current
18 Ia=IT-If;           // Armature current

```



Figure 10.8: Computation of new armature current

```

19 Racir=Ra+Ripcw;           // Resistance of armature
   circuit
20 Ea=VT-Ia*Racir;
21
22
23 // Display result on command window
24 printf("\n Induced emf = %0.0f V ",Ea);

```

Scilab code Exa 10.8 Computation of new armature current

```

1 // Example 10.8
2 // Computation of new armature current
3 // Page No. 420
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 Rf=120;                  // Resistance of inserted
                           resistor

```

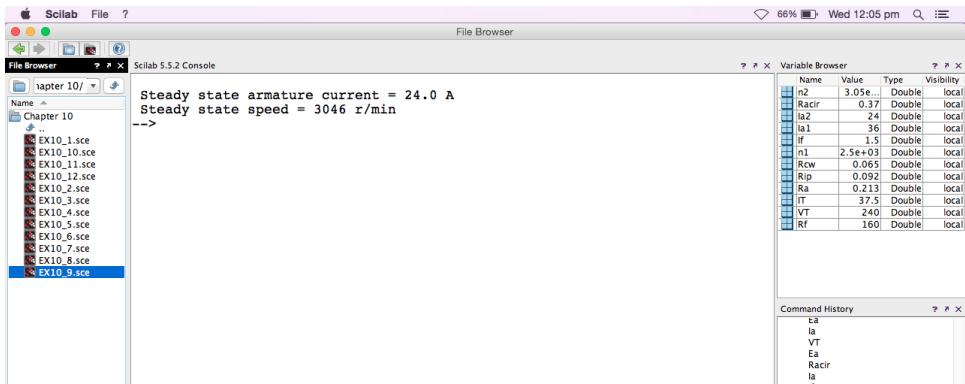


Figure 10.9: Computation of Steady state armature current and Steady state speed

```

11 VT=240; // Rated voltage of the machine
12 IT=91; // Total current
13 Racir=0.221; // Armature circuit resistance
14 n2=634; // New speed after resistor was inserted
15 n1=850; // Rated speed OF THE MACHINE
16 Rx=2.14; // Resistance inserted in series with armature
17
18 // New armature current
19
20 If=VT/Rf; // Resistor current
21 Ia1=IT-If; // Armature current
22 Ia2=(VT-(n2/n1)*(VT-Ia1*Racir))/(Racir+Rx);
23
24
25 // Display result on command window
26 printf("\n New armature current = %0.2f A ",Ia2);

```

Scilab code Exa 10.9 Computation of Steady state armature current and Steady state speed

```
1 // Example 10.9
2 // Computation of (a) Steady state armature current
3 // if a rheostat in the
4 // shunt field circuit reduces flux in air gap to 75
5 // % of its rated value
6 // (b) Steady state speed for the conditions in (a)
7 // Page No. 421
8
9
10
11 // Given data
12 Rf=160;           // Field resistance
13 VT=240;           // Rated voltage of the
14 machine
15 IT=37.5;          // Total current
16 Ra=0.213;          // Armature resistance
17 Rip=0.092;         // Resistance of interpolar
18 winding
19 Rcw=0.065;         // Resistance of compensating
20 windings
21 n1=2500;           // Rated speed of the machine
22
23
24 // (a) At rated conditions
25 If=VT/Rf;           // Field current
26 Ia1=IT-If;           // Armature current
27 Ia2=Ia1*0.50*1/0.75;
```

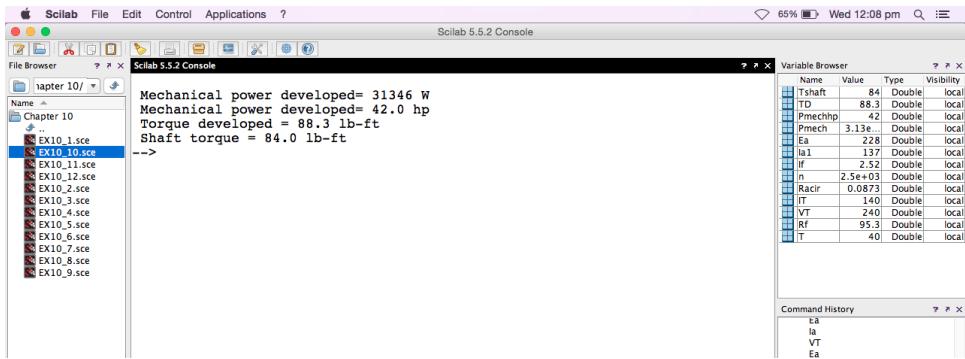


Figure 10.10: Computation of Mechanical power developed and Torque developed and Shaft torque

```

27 // (b) steady state speed for the above mentioned
   conditions
28
29 Racir=Ra+Rip+Rcw;
30
31 n2=n1*(VT-(Ia2*(1+Racir)))/0.75*(1/(VT-(Ia1*Racir)))
   ;
32
33
34 // Display result on command window
35
36 printf("\n Steady state armature current = %0.1f A "
   ,Ia2);
37 printf("\n Steady state speed = %0.0f r/min ",n2);

```

Scilab code Exa 10.10 Computation of Mechanical power developed and Torque developed and Shaft torque

```
1 // Example 10.10
```

```

2 // Computation of (a) Mechanical power developed (b)
   Torque developed
3 // (c) Shaft torque
4 // Page No.427
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 T=40;                      // Hp rating of motor
12 Rf=95.3;                   // Field resistance
13 VT=240;                    // Rated voltage of the
   machine
14 IT=140;                    // Total current
15 Racir=0.0873;              // Armature circuit
   resistance
16 n=2500;                    // Rated speed of the machine
17
18
19 // (a) The mechanical power developed
20
21 If=VT/Rf;                  // Field winding current
22 Ia1=IT-If;                 // Armature current
23 Ea=VT-Ia1*Racir;           // Armature emf
24 Pmech=Ea*Ia1;              // Mechanical power
25 Pmechhp=Ea*Ia1/746;
26
27 // (b) Torque developed
28
29 TD=7.04*Ea*Ia1/n;
30
31 // (c) Shaft torque
32
33 Tshaft=T*5252/n;
34
35 // Display result on command window
36 printf("\n Mechanical power developed= %0.0 f W ",
```

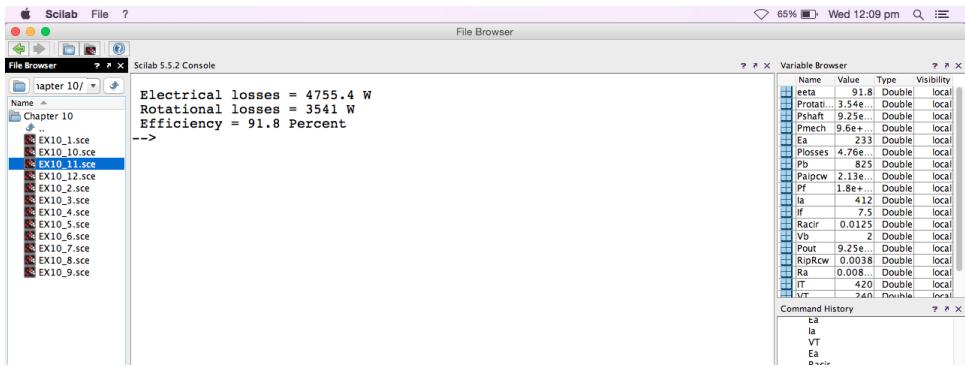


Figure 10.11: Determine Electrical losses and Rotational losses and Efficiency

```

Pmech);
37 printf("\n Mechanical power developed= %0.1f hp ", Pmechhp);
38 printf("\n Torque developed = %0.1f lb-ft ", TD);
39 printf("\n Shaft torque = %0.1f lb-ft ", Tshaft);

```

Scilab code Exa 10.11 Determine Electrical losses and Rotational losses and Efficiency

```

1 // Example 10.11
2 // Determine (a) Electrical losses (b) Rotational
   losses (c) Efficiency
3 // Page No. 430
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 T=124;                                // Hp rating of motor
11 Rf=32.0;                                // Field resistance

```

```

12 VT=240; // Rated voltage of the
           machine
13 IT=420; // Total current
14 Ra=0.00872; // Armature resistance
15 RipRcw=0.0038; // Resistance of
                  interpolar winding and compensating windings
16 Pout=92504;
17 Vb=2.0; // Rated speed of the
            machine
18 Racir=Ra+RipRcw;
19
20 // (a) Electrical losses
21
22 If=VT/Rf; // Field current
23 Ia=IT-If; // Armature current
24 Pf=If^2*Rf; // Field power
25 Paipcw=Ia^2*(Ra+RipRcw); // Brush loss power
26 Pb=Vb*Ia; // Total power loss
27 Plosses=Pf+Paipcw+Pb;
28
29 // (b) Rotational losses
30
31 Ea=VT-(Ia*Racir)-Vb; // Armature emf
32 Pmech=Ea*Ia; // Mechanical power
33 Pshaft=T*746; // Shaft power
34 Protational=Pmech-Pshaft;
35
36 // (c) Efficiency
37
38 eeta=Pout/(VT*IT)*100;
39
40 // Display result on command window
41
42 printf("\n Electrical losses = %0.1f W ",Plosses);
43 printf("\n Rotational losses = %0.0f W ",Protational
       );
44 printf("\n Efficiency = %0.1f Percent ",eeta);

```

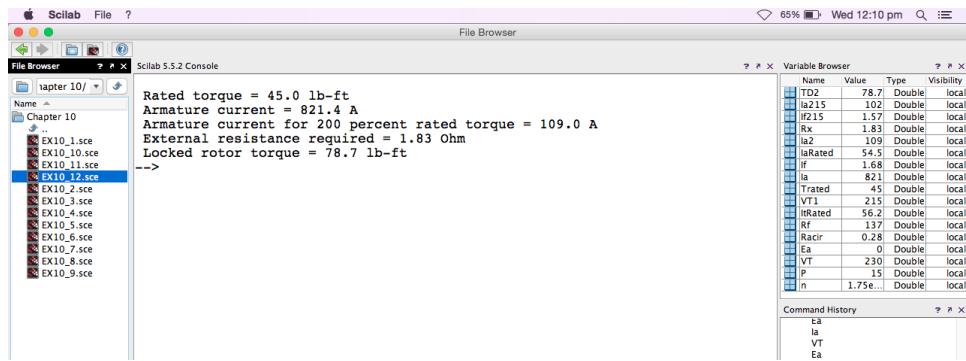


Figure 10.12: Determine Rated torque and Armature current at locked rotor and External resistance required in the armature circuit and Determine the locked rotor torque

Scilab code Exa 10.12 Determine Rated torque and Armature current at locked rotor and External resistance required in the armature circuit and Determine the locked rotor torque

```

1 // Example 10.12
2 // Determine (a) Rated torque (b) Armature current
   at locked rotor if no
3 // starting resistance is used (c) External
   resistance required in the armature
4 // circuit that would limit the current and develop
   200 percent rated torque
5 // when starting (d) Assuming the system voltage
   drops to 215V, determine the
6 // locked rotor torque using the external resistor
   in (c)
7 // Page No. 433
8
9 clc;

```

```

10 clear;
11 close;
12
13 // Given data
14 n=1750;                                // Rotor speed
15 P=15;                                    // Hp rating of motor
16 VT=230;                                  // Rated voltage of the
                                             machine
17 Ea=0;                                   
18 Racir=0.280;                            // Armature circuit loss
19 Rf=137;                                  // Field resistance
20 ItRated=56.2;                            // Total current drawn
21 VT1=215;                                 // Rated voltage after
                                             drop
22
23 // (a) Rated torque
24 Trated=P*5252/n;
25
26 // (b) Armature current
27 Ia=(VT-Ea)/Racir;
28
29 // (c) External resistance required
30 If=VT/Rf;                                // Field current
31 IaRated=ItRated-If;                      // Rated armature
                                             current
32
33 Ia2=IaRated*2;                           // Armature current
                                             for 200% rated torque
34
35 Rx=((VT-Ea)/Ia2)-Racir;                // External
                                             resistance required
36
37 // (d) Locked rotor torque
38 If215=VT1/Rf;                            // Field current at
                                             215V
39 Ia215=(VT1-Ea)/(Racir+Rx);              // Armature current
                                             at 215V
40 TD2=Trated*( (If215*Ia215) / (If*IaRated) );

```

```
41
42 // Display result on command window
43
44 printf("\n Rated torque = %0.1f lb-ft ",Trated);
45 printf("\n Armature current = %0.1f A ",Ia);
46 printf("\n Armature current for 200 percent rated
        torque = %0.1f A ",Ia2);
47 printf("\n External resistance required = %0.2f Ohm
        ",Rx);
48 printf("\n Locked rotor torque = %0.1f lb-ft ",TD2);
```

Chapter 11

Direct Current Motor Characteristics and Applications

Scilab code Exa 11.1 Computation of Armature current when operating at rated conditions and Resistance and power rating of an external resistance required

```
1 // Example 11.1
2 // Computation of (a) The armature current when
   operating at rated conditions
3 // (b) The resistance and power rating of an
   external resistance required in
4 // series with the shunt field circuit to operate at
   125 percent rated speed
5 // Page No. 448
6
7 clc;
8 clear;
9 close;
```

10

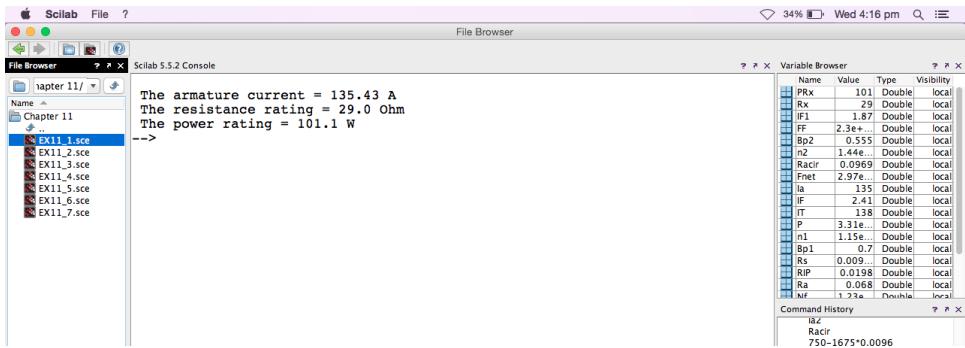


Figure 11.1: Computation of Armature current when operating at rated conditions and Resistance and power rating of an external resistance required

```

11 // Given data
12 HP=40;                                // hp rating of the device
13 Perratedload=0.902;                    // Percentage rated load
14 VT=240;                                // Voltage value of motor
15 RF=99.5;                               // Resistance of shunt motor
16 Nf=1231;                               // Turns per pole of the
                                           shunt motor
17 Ra=0.0680;                            // Armature resistance
18 RIP=0.0198;                           // Interpole winding
                                           resistance
19 Rs=0.00911;                           // Resistance of series
                                           field winding
20 Bp1=0.70;                             // Flux density for a net
                                           mmf
21 n1=1150;                              // Speed of shunt motor
22
23 // (a) The armature current when operating at rated
   conditions
24 P=HP*746/Perratedload;                // Total current
25 IT=P/VT;                               // Field current
26 IF=VT/RF;
27 Ia=IT-IF;
28
29 // (b) The resistance and power rating of an

```

```

        external resistance required in
30 // series with the shunt field circuit to operate at
     125 percent rated speed
31
32 Fnet=Nf*IF;           // Corresponding mmf
     from magnetization curve
33 Racir=Ra+RIP+Rs;
34 n2=n1*1.25;           // 125 percent rated
     speed
35 // Shaft load is adjusted to value that limits the
     armature current to 115%
36 // of rated current
37 Bp2=Bp1*(n1/n2)*((VT-Ia*Racir*1.15)/(VT-Ia*Racir))
38 FF=2.3*1000;
39 IF1=FF/Nf;
40 Rx=(VT/IF1)-RF;
41 PRx=(IF1^2)*Rx;
42
43 // Display result on command window
44 printf("\n The armature current = %0.2f A ",Ia);
45 printf("\n The resistance rating = %0.1f Ohm ",Rx);
46 printf("\n The power rating = %0.1f W ",PRx);
47
48 //Note: Answer varies due to round-off errors

```

Scilab code Exa 11.2 Computation of Shunt field current and Armature current and Developed torque and Armature current and External resistance required

```

1 // Example 11.2
2 // Computation of (a) Shunt field current (b)
     Armature current (c) Developed
3 // torque (d) Armature current if a resistor

```

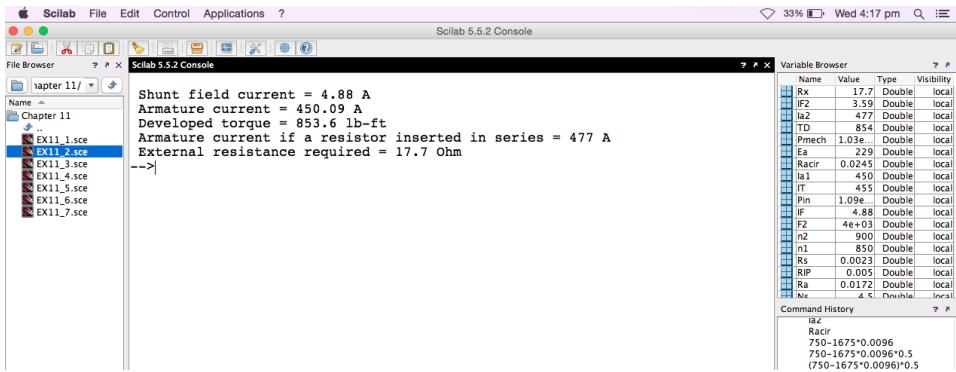


Figure 11.2: Computation of Shunt field current and Armature current and Developed torque and Armature current and External resistance required

```

        inserted in series with the shunt
4 // field circuit caused the speed to increase to 900
      r/min (e) External
5 // resistance required in series with the shunt
      field circuit to operate
6 // at 900 r/min
7 // Page No. 450
8
9 clc;
10 clear;
11 close;
12
13 // Given data
14 HP=125;
15 perratedload=0.854;           // Percentage rated
      load
16 VT=240;                      // Voltage value of
      motor
17 RF=49.2;                     // Resistance of shunt
      motor
18 Nf=577;                      // Turns per pole of
      the shunt motor
19 Ns=4.5;                       // Armature resistance
20 Ra=0.0172;                   // Armature resistance

```

```

21 RIP=0.005; // Interpole winding
   resistance
22 Rs=0.0023; // Resistance of series
   field winding
23 n1=850; // Speed of shunt motor
24 n2=900;
25 F2=4000;
26
27 // (a) Shunt field current
28
29 IF=VT/RF; // Field current
30
31 // (b) Armature current
32 Pin=HP*746/perratedload; // Input power
33 IT=Pin/VT; // Total current
34 Ia1=IT-IF;
35
36 // (c) Developed torque
37
38 Racir=Ra+RIP+Rs;
39 Ea=VT-Ia1*Racir; // Armature emf
40 Pmech=Ea*Ia1; // Mechanical power
41 TD=Pmech*5252/n1/746; // Torque developed
42
43 // (d) Armature current if a resistor inserted in
   series with the shunt field
44 // circuit caused the speed to increase to 900 r/min
45
46 Ia2=Ia1*n2/n1;
47
48 // (e) External resistance required in series with
   the shunt field circuit to
49 // operate at 900 r/min
50 IF2=(F2-0.90*Ns*Ia2)/Nf;
51 Rx=(VT/IF2)-RF;
52
53
54 // Display result on command window

```



Figure 11.3: Computation of Speed if the load is reduced to a value that causes the armature current to be 30 percent of the rated current

```

55 printf("\n Shunt field current = %0.2f A ",IF);
56 printf("\n Armature current = %0.2f A ",Ia1);
57 printf("\n Developed torque = %0.1f lb-ft ",TD);
58 printf("\n Armature current if a resistor inserted
      in series = %0.0f A ",Ia2);
59 printf("\n External resistance required = %0.1f Ohm
      ",Rx);

```

Scilab code Exa 11.3 Computation of Speed if the load is reduced to a value that causes the armature current to be 30 percent of the rated current

```

1 // Example 11.3
2 // Computation of Speed if the load is reduced to a
   value that causes the
3 // armature current to be 30 percent of the rated
   current
4 // Page No.453
5
6 clc;
7 clear;

```

```

8 close;
9
10 // Given data
11 HP=100;
12 perratedload=0.896;           // Percentage rated load
13 VT=240;                      // Voltage value of motor
14 Ns=14;                       // Number of turns/pole in
                                series field
15 Ra=0.0202;                  // Armature resistance
16 RIP=0.00588;                // Interpole winding
                                resistance
17 Rs=0.00272;                 // Resistance of series
                                field winding
18 n1=650;                      // Speed of shunt motor
19 Bp2=0.34;                    // Air gap flux density from
                                magnetization curve
20 Bp1=0.87;                    // Air gap flux density from
                                magnetization curve
21
22 // Computation of Speed if the load is reduced to a
   value that causes the
23 // armature current to be 30 percent of the rated
   current
24
25 Pin=HP*746/perratedload;    // Input power
26 IT=Pin/VT;                  // Total current
27 Ia=IT;                      // Armature current
28
29 Racir=Ra+RIP+Rs;           // Resistance of
                                armature circuit
30 Fnet1=Ns*Ia*(1-0.080);     // Net mmf
31 Fnet2=0.30*Fnet1;          // Net mmf from
                                magnetization curve
32 n2=n1/((VT-(Ia*Racir))/Bp1 * Bp2/(VT-(0.30*Ia*Racir)
      ));
33
34 // Display result on command window
35 printf("\n Speed of the motor = %0.0 f r/min ",n2);

```

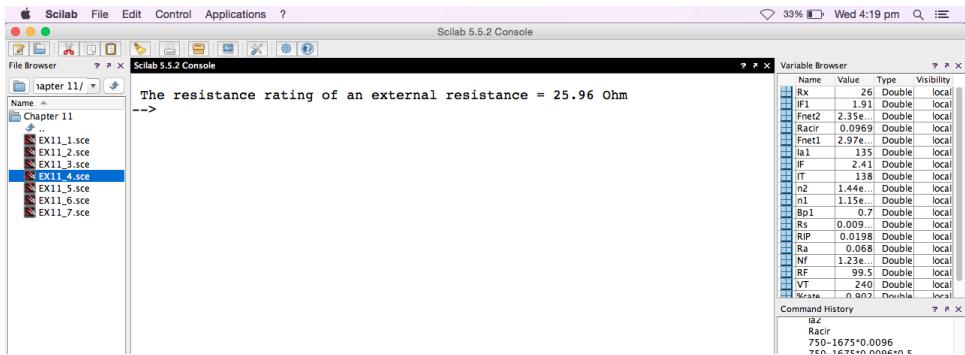


Figure 11.4: Computation of resistance using linear approximation and values are compared with results obtained in previous example

Scilab code Exa 11.4 Computation of resistance using linear approximation and values are compared with results obtained in previous example

```

1 // Example 11.4
2 // Computation of resistance using linear
   approximation and values are
3 // compared with results obtained in example 11.1
4 // Page No. 456
5 clc;
6 clear;
7 close;
8
9 // Given data
10 HP=40;                                // hp rating of the device
11 %ratedload=0.902;                      // Percentage rated load
12 VT=240;                                // Voltage value of motor
13 RF=99.5;                               // Resistance of shunt
   motor

```

```

14 Nf=1231;                                // Turns per pole of the
                                             shunt motor
15 Ra=0.0680;                                // Armature resistance
16 RIP=0.0198;                                // Interpole winding
                                             resistance
17 Rs=0.00911;                                // Resistance of series
                                             field winding
18 Bp1=0.70;                                  // Flux density for a net
                                             mmf
19 n1=1150;                                   // Speed of shunt motor
20 n2=1.25*n1;
21 IT=137.84;
22 // Computation of resistance using linear
                                             approximation and values are
23 // compared with results obtained in example 11.1
24
25 IF=VT/RF;                                 // Field current
26 Ia1=IT-IF;                                // Armature current
27 Fnet1=Nf*IF;                                // Net mmf
28 Racir=Ra+RIP+Rs;                            // Armature circuit
                                             resistance
29 Fnet2=Fnet1*(n1/n2)*((VT-Ia1*Racir*1.15)/(VT-Ia1*
                                             Racir));
30 IF1=Fnet2/Nf;                                // Field current
31 Rx=(VT/IF1)-RF;                            // External resistance
                                             required
32
33
34 // Display result on command window
35 printf("\n The resistance rating of an external
                                             resistance = %0.2f Ohm ",Rx);

```

Scilab code Exa 11.5 Computation using linear approximation to show

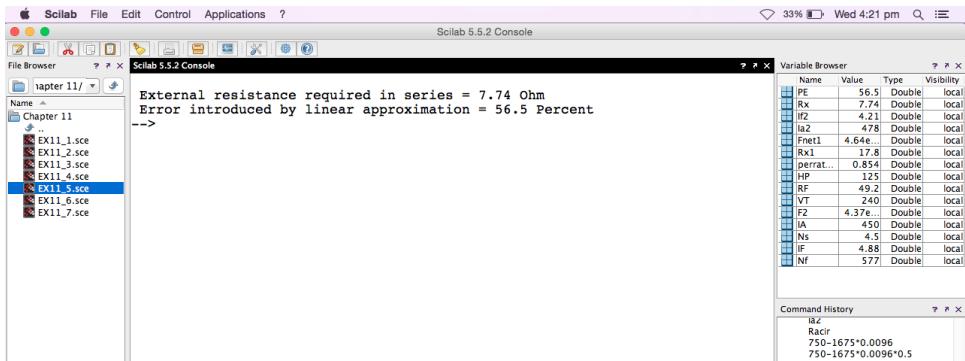


Figure 11.5: Computation using linear approximation to show the gross error that occurs when a linear assumption is applied to compound motors operating at overload conditions

the gross error that occurs when a linear assumption is applied to compound motors operating at overload conditions

```

1 // Example 11.5
2 // Computation using linear approximation to show
   the gross error that occurs
3 // when a linear assumption is applied to compound
   motors operating at overload
4 // conditions
5 // Page No. 456
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 Nf=577;                                // Turns per pole of the
                                             shunt motor
13 IF=4.88;                                 // Field current
14 Ns=4.5;                                  // Armature current
15 IA=450.09;                               // mmf
16 F2=4367.8;                              // Voltage value of motor
17 VT=240;

```

```

18 RF=49.2; // Resistance of shunt
    motor
19 HP=125;
20 perratedload=0.854; // Percentage rated load
21 Rx1=17.8; // Value of resistance in
    Example 11.2
22
23
24 Fnet1=(Nf*IF)+(0.90 * Ns*IA);
25 Ia2=Fnet1*IA/F2; // Armature current
26
27 If2=(F2 - Ns*Ia2*0.90)/Nf;
28 Rx=(VT/If2)-RF; // External resistance
    required
29
30 // Error introduced by linear approximation
31 PE=(17.8-Rx)/17.8*100;
32
33 // Display result on command window
34 printf("\n External resistance required in series =
    %0.2f Ohm ",Rx);
35 printf("\n Error introduced by linear approximation
    = %0.1f Percent ",PE);

```

Scilab code Exa 11.6 Determine Torque developed when operating at rated speed and Developed torque required at half rated speed and Armature voltage required for half rated speed

```

1 // Example 11.6
2 // Determine (a) Torque developed when operating at
    rated speed (b) Developed
3 // torque required at half rated speed (c) Armature
    voltage required for half

```

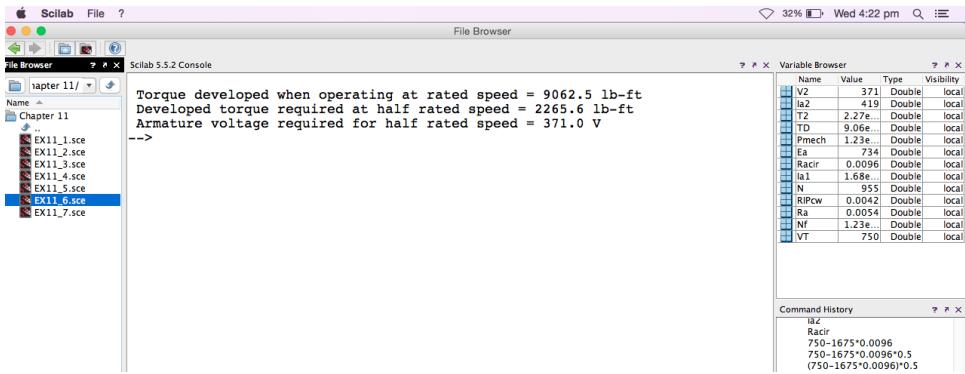


Figure 11.6: Determine Torque developed when operating at rated speed and Developed torque required at half rated speed and Armature voltage required for half rated speed

```

4 // rated speed
5 // Page No. 460
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12
13 VT=750; // Voltage value of motor
14 Nf=1231; // Turns per pole of the
             shunt motor
15 Ra=0.00540; // Armature resistance
16 RIPcw=0.00420; // Interpole winding
                  resistance
17 N=955; // Speed of shunt motor
18 Ia1=1675; // Armature current
19
20 // (a) Torque developed when operating at rated
      speed
21
22 Racir=Ra+RIPcw;
23 Ea=VT-Ia1*Racir;

```

```

24 Pmech=Ea*Ia1;
25 TD=Pmech*5252/N/746;
26
27 // (b) Developed torque required at half rated speed
28
29 T2=TD*(0.5*N/N)^2;
30
31 // (c) Armature voltage required for half rated
32 speed
33 Ia2=T2*Ia1/TD;
34 V2=(0.5*N/N)*(VT-Ia1*Racir) + Ia2*Racir ;
35
36 // Shaft load is adjusted to value that limits the
37 armature current to 115 % of rated current
38
39 printf("\n Torque developed when operating at rated
40 speed = %0.1f lb-ft ",TD);
41 printf("\n Developed torque required at half rated
42 speed = %0.1f lb-ft ",T2);
43 printf("\n Armature voltage required for half rated
44 speed = %0.1f V ",V2);

```

Scilab code Exa 11.7 Computation of the resistance of a dynamic braking resistor that will be capable of developing 500 lb ft of braking torque at a speed of 1000 rpm

```

1 // Example 11.7
2 // Computation of the resistance of a dynamic
3 // braking resistor that will be
4 // capable of developing 500 lb-ft of braking torque
5 // at a speed of 1000 r/min.

```

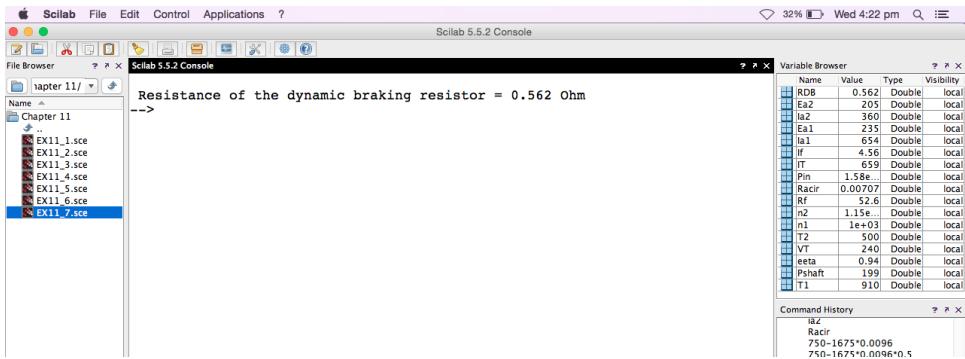


Figure 11.7: Computation of the resistance of a dynamic braking resistor that will be capable of developing 500 lb ft of braking torque at a speed of 1000 rpm

```

4 // Page No. 464
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 T1=910;                                // Torque load
12 Pshaft=199.257*746;                     // Power of shaft
13 eeta=0.940;                            // Efficiency
14 VT=240;                                 // Rated voltage
15 T2=500;                                 // Braking torque
16 n1=1000;                               // Windage and
                                         friction speed
17 n2=1150;                               // Speed of motor
18 Rf=52.6;                                // Field resistance
19 Racir=0.00707;                         // Combined
                                         armature , compensating winding and
                                         interpolar resistance
20
21 // Resistance of a dynamic braking resistor
22 Pshaft=T1*n2/5252;                      // Shaft power

```

```
23 Pin=Pshaft*746/eeta;           // Input power
24 IT=Pin/VT;                   // Total current
25 If=VT/Rf;                   // Field current
26 Ia1=IT-If;                  // Armature current
27 Ea1=VT-Ia1*Racir;          // Armature emf
28
29 Ia2=Ia1*T2/T1;             // Armature current
30 Ea2=Ea1*n1/n2;
31 RDB=(Ea2-Ia2*Racir)/Ia2;   // Resistance
32
33 //Display result on command window
34 printf("\n Resistance of the dynamic braking
resistor = %0.3f Ohm ",RDB);
```

Chapter 12

Direct Current Generator Characteristics and Operation

Scilab code Exa 12.1 Determine Field circuit resistance and Field rheostat setting and Armature voltage and Field rheostat setting that will cause critical resistance and Armature voltage

```
1 // Example 12.1
2 // Determine (a) Field circuit resistance (b) Field
   rheostat setting that will
3 // provide no load voltage of 140V (c) Armature
   voltage if the rheostat is set
4 // to 14.23 ohm (d) Field rheostat setting that will
   cause critical resistance
5 // (e) Armature voltage at 80 percent rated speed (f)
   ) Rheostat setting required
6 // to obtain no load armature voltage of 140V if
   shunt field is separately
7 // excited from a 120V DC source
8 // Page No. 479
9
10 clc;
```

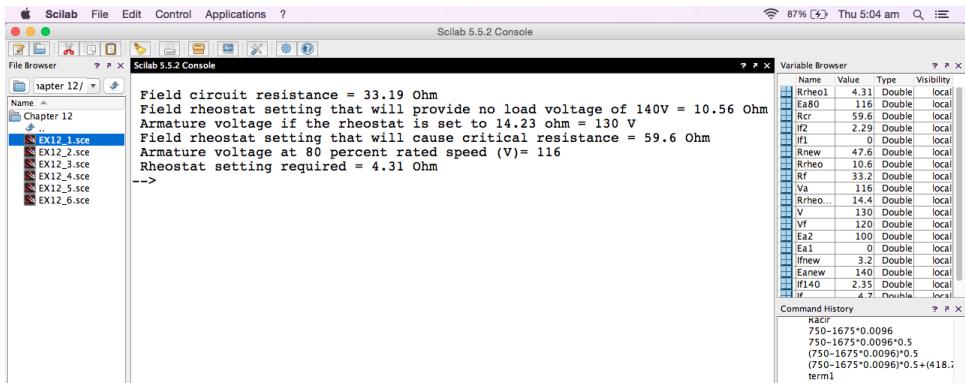


Figure 12.1: Determine Field circuit resistance and Field rheostat setting and Armature voltage and Field rheostat setting that will cause critical resistance and Armature voltage

```

11 clear;
12 close;
13
14 // Given data
15 Ea=156;                      // No load voltage
16 If=4.7;                       // Shunt field current
17 If140=2.35;                   // New field current at Ea=140
18                                     V
18 Eanew=140;                   // No load voltage
19 Ifnew=3.2;                     // Field current corresponding
20                                     to no load voltage
21 Ea1=0;                         // First arbitrary voltage
22 Ea2=100;                        // Second arbitrary voltage
22 Vf=120;                        // Intersection of I1 and I2
23 V=130;                          // Intersection of I1 and I2
24 Rrheonew=14.42;                // Rheostat set to new
25                                     settings
25 Va=116;                        // Intersection of field
26                                     resistance line with the low
27                                     speed magnetization curve
28

```

```

29
30 // (a) Field circuit resistance
31 Rf=Ea/IIf;           // Field circuit resistance
32
33 // (b) Field rheostat setting that will provide no
   load voltage of 140V
34 Rrheo=(Eanew/IIfnew)-Rf;
35
36 // (c) Armature voltage if the rheostat is set to
   14.23 ohm
37 Rnew=Rf+Rrheonew;      // New field resistance
38 If1=Ea1/(Rf+Rrheo);    // Field current
   corresponding to first arbitrary voltage
39 If2=Ea2/(Rf+Rrheo);    // Field current
   corresponding to second arbitrary voltage
40
41 // (d) Field rheostat setting that will cause
   critical resistance
42 Rcr=Eanew/If140;        // Critical resistance
43
44 // (e) Armature voltage at 80 percent rated speed
45 // Ea80=0.80*Ea;
46 Ea80=116;
47
48 // (f) Rheostat setting required to obtain no load
   armature voltage of 140V if
49 // shunt field is separately excited from a 120V DC
   source
50 Rrheo1=(Vf/IIfnew)-Rf;
51
52 // Display result on command window
53 printf("\n Field circuit resistance = %0.2f Ohm",Rf)
   ;
54 printf("\n Field rheostat setting that will provide
   no load voltage of 140V = %0.2f Ohm ",Rrheo);
55 printf("\n Armature voltage if the rheostat is set
   to 14.23 ohm = %0.0f V ",V);
56 printf("\n Field rheostat setting that will cause

```

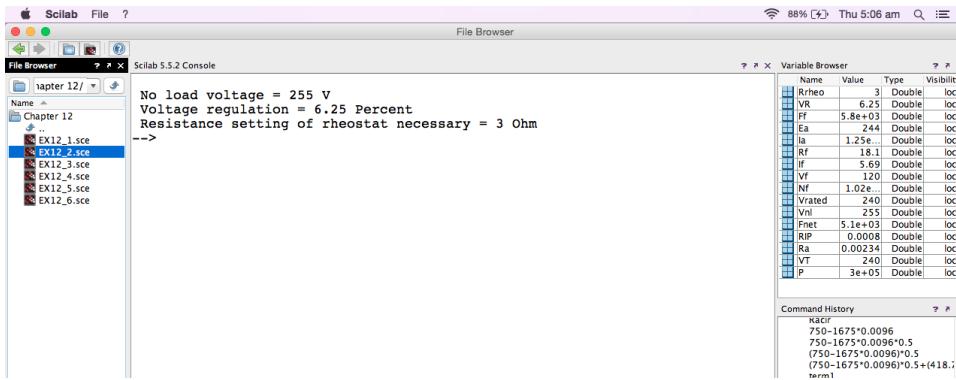


Figure 12.2: Computation of No load voltage and Voltage regulation and Resistance setting of rheostat necessary to obtain rated voltage

```
critical resistance = %0.1f Ohm ",Rcr);
57 printf("\n Armature voltage at 80 percent rated
      speed (V)= %0.0f   ",Ea80);
58 printf("\n Rheostat setting required = %0.2f Ohm " ,
      Rrheo1);
```

Scilab code Exa 12.2 Computation of No load voltage and Voltage regulation and Resistance setting of rheostat necessary to obtain rated voltage

```
1 // Example 12.2
2 // Computation of (a) No load voltage (b) Voltage
   regulation
3 // (c) Resistance setting of rheostat necessary to
   obtain rated voltage
4 // at rated conditions
5 // Page No. 487
6
7 clc;
8 clear;
```

```

9  close;
10
11 // Given data
12 P=300000; // Shunt generator power
13 rating
13 VT=240; // Shunt generator voltage
14 Ra=0.00234; // Armature winding
14 resistance
15 RIP=0.00080; // Resistance of interpole
15 winding
16 Fnet=5100; // Net mmf
17 Vnl=255; // No load voltage
18 Vrated=240; // Rated voltage
19 Nf=1020; // Turns per pole
20 Vf=120; // Source that separately
20 excites the generator
21 If=5.69;
22 Rf=18.1;
23
24 // (a) No load voltage
25 Ia=P/VT; // Armature current
26 Ea=VT+Ia*(Ra+RIP); // Armature emf
27 Ff=Fnet/(1-0.121);
28
29
30 // (b) Voltage regulation
31 VR=(Vnl-Vrated)*100/Vrated;
32
33 // (c) Resistance setting of rheostat necessary to
33 obtain rated voltage at rated conditions
34 If=Ff/Nf;
35 Rrheo=(Vf/If)-Rf; // Rheostat setting
36
37
38 // Display result on command window
39 printf("\n No load voltage = %0.0 f V ",Vnl);
40 printf("\n Voltage regulation = %0.2 f Percent ",VR);

```

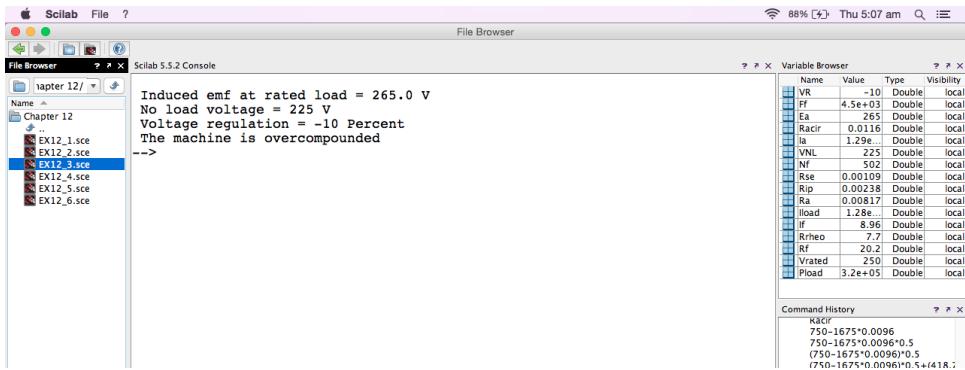


Figure 12.3: Computation of Induced emf at rated load and No load voltage and Voltage regulation

```

41 printf("\n Resistance setting of rheostat necessary
      = %0.0 f Ohm", Rrheo);

```

Scilab code Exa 12.3 Computation of Induced emf at rated load and No load voltage and Voltage regulation

```

1 // Example 12.3
2 // Computation of (a) Induced emf at rated load (b)
   No load voltage
3 // (c) Voltage regulation (d) What is the type of
   compounding?
4 // Page No. 492
5
6 clc;
7 clear;
8 close;
9
10 // Given data
11 Pload=320000; // Shunt generator power
                  rating

```

```

12 Vrated=250; // Shunt generator
    voltage rating
13 Rf=20.2; // Shunt resistance
14 Rrheo=7.70; // Shunt field rheostat
    value
15 If=8.96; // Field current
16 Iload=1280; // Load current
17 Ra=0.00817; // Armature resistance
18 Rip=0.00238; // Resistance of
    interpole winding
19 Rse=0.00109; // Resistance of series
    winding
20 Nf=502; // Turns per pole
21 VNL=225; // No load voltage
22
23 // (a) Induced emf at rated load
24 Iload=Pload/Vrated; // Load current
25 If=Vrated/(Rf+Rrheo); // Field current
26 Ia=If+Iload; // Armature current
27 Racir=Ra+Rip+Rse;
28 Ea=Vrated+Ia*Racir;
29
30 // (b) No load voltage
31 Ff=Nf*If;
32
33 // (c) Voltage regulation
34 VR=(VNL-Vrated)*100/Vrated;
35
36
37 // Display result on command window
38 printf("\n Induced emf at rated load = %0.1f V ",Ea)
    ;
39 printf("\n No load voltage = %0.0f V ",VNL);
40 printf("\n Voltage regulation = %0.0f Percent ",VR);
41 printf("\n The machine is overcompounded ");

```

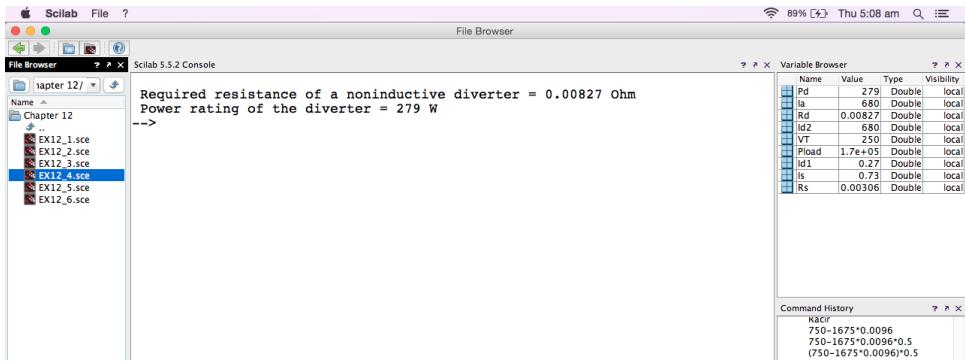


Figure 12.4: Computation of Required resistance of a noninductive diverter that will bypass 27 percent of the total armature current and Power rating of the diverter

Scilab code Exa 12.4 Computation of Required resistance of a noninductive diverter that will bypass 27 percent of the total armature current and Power rating of the diverter

```

1 // Example 12.4
2 // Computation of (a) Required resistance of a
   noninductive diverter that will
3 // bypass 27 percent of the total armature current (b)
   // Power rating of the
4 // diverter
5 // Page No. 494
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 Rs=0.00306;           // Shunt generator

```

```

    resistance rating
13 Is=0.73;                                // Shunt generator current
     rating
14 Id1=0.27;                                // Armature winding
     resistance
15 Pload=170000;                            // Load of power
16 VT=250;                                   // Shunt generator voltage
     rating
17 Id2=680;                                  // No load voltage
18 Rd=0.27;                                   // Resistance drop
19
20 // (a) Required resistance of a noninductive
     diverter that will bypass
21 // 27 percent of the total armature current
22 Rd=Rs*Is/Id1;
23
24
25 // (b) Power rating of the diverter
26 Ia=Pload/VT;
27 Pd=((Id1*Id2)^2)*Rd;
28
29
30
31 //Display result on command window
32 printf("\n Required resistance of a noninductive
     diverter = %0.5f Ohm ",Rd);
33 printf("\n Power rating of the diverter = %0.0f W ",
     Pd);

```

Scilab code Exa 12.5 Computation of New bus voltage and Current supplied by each generator

```
1 // Example 12.5
```

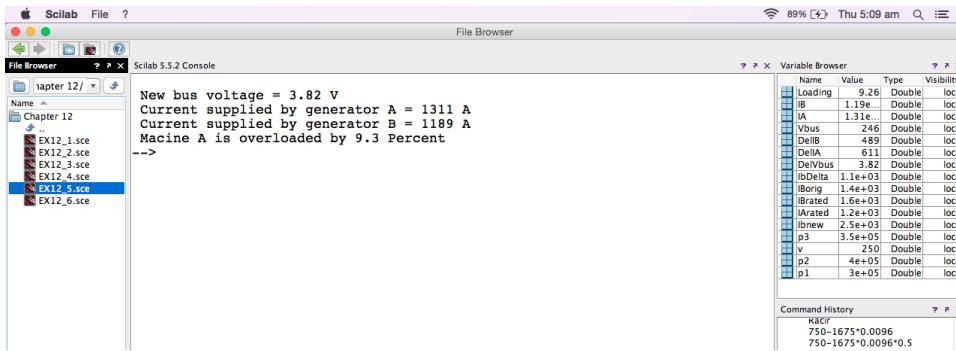


Figure 12.5: Computation of New bus voltage and Current supplied by each generator

```

2 // Computation of (a) New bus voltage (b) Current
     supplied by each generator
3 //Page No. 500
4
5 clc;
6 clear;
7 close;
8
9 // Given data
10 p1=300000;                      // Rated power in generator
      A
11 p2=400000;                      // Rated power in generator
      B
12 v=250;                          // Rated voltage in machine
13 p3=350000;                      // Rated power in generator
      C
14 Ibnew=2500;
15
16 // (a) New bus voltage
17
18 IArated=p1/v;                  // Rated current in
      generator A
19 IBrated=p2/v;                  // Rated current in
      generator B

```

```

20 IBorig=p3/v;           // Original bus current
21 IbDelta=Ibnew-IBorig; // Current difference
22 DelVbus=IbDelta/(160+128); // Voltage difference
23
24
25 // (b) Current supplied by each generator
26 DelIA=160*DelVbus;      // Generator A current
   difference
27 DelIB=128*DelVbus;      // Generator A current
   difference
28 Vbus=v-DelVbus;         // Voltage across the
   bus
29 IA=700+DelIA;           // Current in generator
   A
30 IB=700+DelIB;           // Current in generator
   B
31
32 Loading= (IA-IArated)*100/IArated;
33
34
35 // Display result on command window
36 printf("\n New bus voltage = %0.2f V ",DelVbus);
37 printf("\n Current supplied by generator A = %0.0f A
   ",IA);
38 printf("\n Current supplied by generator B = %0.0f A
   ",IB);
39 printf("\n Machine A is overloaded by %0.1f Percent "
   ,Loading);

```

Scilab code Exa 12.6 Determine the increment increase in load on each machine if an additional 400 A load is connected to the bus and Current carried by each machine

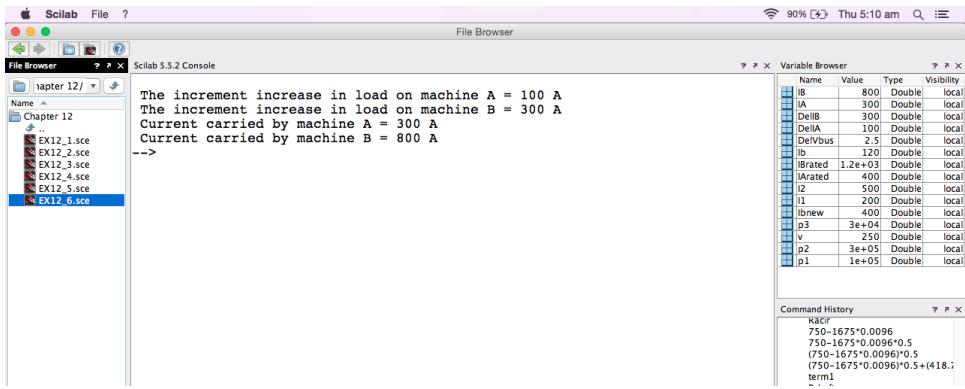


Figure 12.6: Determine the increment increase in load on each machine if an additional 400 A load is connected to the bus and Current carried by each machine

```

1 // Example 12.6
2 // Determine (a) The increment increase in load on
   each machine if an
3 // additional 400 A load is connected to the bus (b)
   Current carried
4 // by each machine
5 // Page No. 502
6
7 clc;
8 clear;
9 close;
10
11 // Given data
12 p1=100000;                                // Rated power in
   generator A
13 p2=300000;                                // Rated power in
   generator B
14 v=250;                                     // Rated voltage in
   machine
15 p3=30000;                                // Rated power in
   generator C
16 Ibnew=400;                                 // New bus current
17 I1=200;
```

```

18 I2=500;
19
20 // (a) The increment increase in load on each
   machine if an additional 400 A
21 // load is connected to the bus
22
23 IArated=p1/v;                                // Rated current
   in generator A
24 IBrated=p2/v;                                // Rated current
   in generator B
25 Ib=p3/v;                                    // Original bus
   current
26 DelVbus=Ibnew/(40+120);                     // Change in bus
   current
27 DelIA=40*DelVbus;
28 DelIB=120*DelVbus;
29
30
31 // (b) Current carried by each machine
32
33 IA=I1+DelIA;                                // Current in generator
   A
34 IB=I2+DelIB;                                // Current in generator
   B
35
36
37 // Display result on command window
38 printf("\n The increment increase in load on machine
   A = %0.0f A ",DelIA);
39 printf("\n The increment increase in load on machine
   B = %0.0f A ",DelIB);
40 printf("\n Current carried by machine A = %0.0f A ",
   IA);
41 printf("\n Current carried by machine B = %0.0f A ",
   IB);

```
