Scilab Textbook Companion for
Power System Operation and Control
by B. R. Gupta[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Introduction

Scilab code Exa 1.1 Load Demand and energy

```
1  //exa 1.1
2  clc;clear;close;
3  format('v',6);
4  B=100;//W(8 Bulb)
5  F=60;//W(2 Fan)
6  L=100;//W(2 Light)
7  LoadConnected=8*B+2*F+2*L;//W
8  disp(LoadConnected,"(a) Connected Load (W)")
9  //12 midnight to 5am
10 demand1=1*F;//W
11 //5am to 7am
12 demand2=2*F+1*L;//W
13 //7am to 9am
14 demand3=0;//W
15 //9am to 6pm
16 demand4=2*F;//W
17 //6pm to midnight
18 demand5=2*F+4*B;//W
19 DEMAND=[demand1 demand2 demand3 demand4 demand5]
20 max_demand=max(DEMAND);
21 disp(max_demand,"(b) Maximum demand (W)");
```

```
22 df = max_demand / LoadConnected ; // demand factor
23 disp ( df ," ( c ) Demand factor " ) ;
24 E = demand1 *5+ demand2 *2+ demand3 *2+ demand4 *9+ demand5 *6;
     // Wh
25 E = E /1000; // kWh
26 disp (E ," ( d ) Energy consumed during 24 hours ( kWh ) " )
27 Edash = LoadConnected *24/1000; // kWh
28  disp ( Edash ," ( e ) Energy consumed during 24 hours if
        all devices are used ( kWh ) " )
```

Scilab code Exa 1.2 Demand and Diversity Factor

```
 1 // exa 1.2
 2 clc ; clear ; close ;
 3 format ( 'v' ,6) ;
 4 LoadA =2.5*1000; // W
 5 //12 midnight to 5am
 6 d1A =100; // W
 7 //5am to 6am
 8 d2A =1.1*1000; // W
 9 //6am to 8am
10 d3A =200; // W
11 //8am to 5pm
12 d4A =0; // W
13 //5pm to 12 midnight
14 d5A =500; // W
15 LoadB =3*1000; // W
16 //11 pm to 7am
17 d1B =0; // W
18 //7 am to 8 am
19 d2B =300; // W
20 //8 am to 10 am
21 d3B =1*1000; // W
22 //10 am to 6 pm
23 d4B =200; // W
```

```
24  //6 pm to 11 pm
25  d5B=600;//W
26  DEMAND_A=[d1A d2A d3A d4A d5A];//W
27  DEMAND_B=[d1B d2B d3B d4B d5B];//W
28  max_demand_A=max(DEMAND_A);//W
29  max_demand_B=max(DEMAND_B);//W
30  df_A=max_demand_A/LoadA;//demand factor
31  df_B=max_demand_B/LoadB;//demand factor
32  disp(df_B,df_A,"Demand factor of consumer A & B are"
        );
33  gd_factor=(max_demand_A+max_demand_B)/max_demand_A;
34  disp(gd_factor,"Group diversity factor")
35  E_A=d1A*5+d2A*1+d3A*2+d4A*9+d5A*7;//Wh
36  E_B=d1B*8+d2B*1+d3B*2+d4B*8+d5B*5;//Wh
37  E_A=E_A/1000;//kWh
38  E_B=E_B/1000;//kWh
39  disp(E_B,E_A,"Energy consumed by A & B during 24
        hours(kWh)")
40  Emax_A=max_demand_A*24/1000;//kWh
41  Emax_B=max_demand_B*24/1000;//kWh
42   disp(Emax_B,Emax_A,"Maximum energy consumer A & B
        can consume during 24 hours(kWh)")
43  ratio_A=E_A/Emax_A;
44  format('v',7);
45  ratio_B=E_B/Emax_B;
46  disp(ratio_B,ratio_A,"Ratio of actual energy to
        maximum energy of consumer A & B")
```

Scilab code Exa 1.3 Increase in peak demand

```
1  //exa 1.3
2  clc;clear;close;
3  format('v',6);
4  n1=600;//No. of apartments
5  L1=5;//kW//Each Apartment Load
```

```
 6  n2=20;//No. of general purpose shops
 7  L2=2;//kW//Each Shop Load
 8  df=0.8;//demand factor
 9  //1 Floor mill
10  L3=10;//kW//Load
11  df3=0.7;//demand factor
12  //1 Saw mill
13  L4=5;//kW//Load
14  df4=0.8;//demand factor
15  //1 Laundry
16  L5=20;//kW//Load
17  df5=0.65;//demand factor
18  //1 Cinema
19  L6=80;//kW//Load
20  df6=0.5;//demand factor
21  //Street lights
22  n7=200;//no. of tube lights
23  L7=40;//W//Load of each light
24  //Residential Load
25  df8=0.5;//demand factor
26  gdf_r=3;//group diversity factor
27  pdf_r=1.25;//peak diversity factor
28  //Commertial Load
29  gdf_c=2;//group diversity factor
30  pdf_c=1.6;//peak diversity factor
31  //Solution :
32  //Maximum demand of each apartment
33  dmax_1a=L1*df8;//kW
34  //Maximum demand of 600 apartment
35  dmax_a=n1*dmax_1a/gdf_r;//kW
36  //demand of apartments at system peak time
37  d_a_sp=dmax_a/pdf_r;//kW
38  //Maximum Commercial demand
39  dmax_c=(n2*L2*df+L3*df3+L4*df4+L5*df5+L6*df6)/gdf_c;
        //kW
40  //Commercial demand at system peak time
41  d_c_sp=dmax_c/pdf_c;//kW
42  //demand of street light at system peak time
```

```
43  d_sl_sp=n7*L7/1000; //kW
44  //Increase in system peak demand
45  DI=d_a_sp+d_c_sp+d_sl_sp; //kW
46  disp(DI,"Increase in system peak demand(kW)");
```

Scilab code Exa 1.4 Load Factor and Energy Supplied

```
 1  //exa 1.4
 2  clc;clear;close;
 3  format('v',6);
 4  //12 to 5 am
 5  L1=20; //MW
 6  t1=5; //hours
 7  //5 to 9 am
 8  L2=40; //MW
 9  t2=4; //hours
10  //9 to 6 pm
11  L3=80; //MW
12  t3=9; //hours
13  //6 to 10 pm
14  L4=100; //MW
15  t4=4; //hours
16  //10 to 12 am
17  L5=20; //MW
18  t5=2; //hours
19  //Energy Poduced in 24 hours
20  E=L1*t1+L2*t2+L3*t3+L4*t4+L5*t5; //MWh
21  disp(E,"Energy Supplied by the plant in 24 hours(MWh
        ) :");
22  LF=E/24; //%//Load Factor
23  disp(LF,"Load Factor(%)");
```

Scilab code Exa 1.5 Capacity and utilisation factor

9

```
1  //exa 1.5
2  clc;clear;close;
3  format('v',6);
4  C=125;//MW//Installed Capacity
5  //12 to 5 am
6  L1=20;//MW
7  t1=5;//hours
8  //5 to 9 am
9  L2=40;//MW
10 t2=4;//hours
11 //9 to 6 pm
12 L3=80;//MW
13 t3=9;//hours
14 //6 to 10 pm
15 L4=100;//MW
16 t4=4;//hours
17 //10 to 12 am
18 L5=20;//MW
19 t5=2;//hours
20 //Energy Poduced in 24 hours
21 E=L1*t1+L2*t2+L3*t3+L4*t4+L5*t5;//MWh
22 LF=E/24;//%//Load Factor
23 CF=LF/C;//%//Capacity Factor
24 disp(CF,"Capacity Factor(%) : ");
25 UF=100/C;//%//Utilisation Factor
26 disp(UF,"Utilisation Factor(%) : ");
```

Scilab code Exa 1.6 Energy Load curve and Mass Curve

```
1  //exa 1.6
2  clc;clear;close;
3  format('v',6);
4  //12 to 5 am & 10 to 12 am
5  L1=20;//MW
6  E1=L1*24;//MWh
```

```
7   //5 to 9 am
8   L2=40;//MW
9   E2=E1+(L2-L1)*17;//MWh
10  //9 to 6 pm
11  L3=80;//MW
12  E3=E2+(L3-L2)*13;//MWh
13  //6 to 10 pm
14  L4=100;//MW
15  E4=E3+(L4-L3)*4;//MWh
16  //Plotting Energy load curve
17  L=[0,L1,L2,L3,L4];//MW
18  E=[0,E1,E2,E3,E4];//Mwh
19  subplot(2,1,1)
20  plot(E,L)
21  xlabel('Energy(MWh)');
22  ylabel('Load(MW)');
23  title('Energy Load Curve');
24  //Energy Supplied
25  //Upto 5am
26  t1=5;//hours
27  E1=L1*t1;//MWh
28  //Upto 9am
29  t2=4;//hours
30  E2=E1+L2*t2;//MWh
31  //Upto 6pm
32  t3=9;//hours
33  E3=E2+L3*t3;//MWh
34  //Upto 10pm
35  t4=4;//hours
36  E4=E3+L4*t4;//MWh
37  //Upto 12pm
38  t4=2;//hours
39  E4=E3+L4*t4;//MWh
40  //Plotting Mass curve
41  T=[0,1,2,3,4];//MW
42  E=[0,E1,E2,E3,E4];//Mwh
43  subplot(2,1,2)
44  plot(T,E)
```

```
45  ylabel('Energy(MWh)');
46  xlabel('0-1: 12-5am 1-2: 5-9am 2-3: 9-6pm 3-4: 6-10
        pm above4: 10-12pm');
47  title('Mass Curve');
```

Scilab code Exa 1.7 `Load Factor Plant capacity reserve capacity`

```
1  //exa 1.7
2  clc;clear;close;
3  format('v',9);
4  dmax=40;//MW//Maximum demand
5  CF=0.5;//Capacity Factor
6  UF=0.8;//Utilisation Factor
7  LF=CF/UF;///Load Factor
8  disp(LF,"(a) Load Factor : ");
9  C=dmax/UF;//MW//Plant Capacity
10 disp(C,"(b) Plant Capacity(MW) : ");
11 RC=C-dmax;//MW//Reserve Capacity
12 disp(RC,"(c) Reserve Capacity(MW) : ");
13 p=dmax*LF*24*365;//MWh//Annual Energy Production
14 disp(p,"(d) Annual Energy Production(MWh) : ");
```

Scilab code Exa 1.8 `Load Curve and energy required`

```
1  //exa 1.8
2  clc;clear;close;
3  format('v',6);
4  L1=50;//MW//Initial
5  t1=5;//hours
6  L2=50;//MW//5am
7  t2=4;//hours
8  L3=100;//MW//9am
9  t3=9;//hours
```

```
10  L4=100;//MW//6pm
11  t4=2;//hours
12  L5=150;//MW//8pm
13  t5=2;//hours
14  L6=80;//MW//10pm
15  t6=2;//hours
16  L7=50;//MW
17  //Energy Required in 24 hours
18  E=L1*t1+(L2+L3)/2*t2+(L3+L4)/2*t3+(L4+L5)/2*t4+(L5+
        L6)/2*t5+(L6+L1)/2*t6;//MWh
19  disp(E,"Energy required in one day(MWh)");
20  DLF=E/L5/24*100;//%//Daily Load Factor
21  disp(DLF,"Daily Load Factor(%)");
22  //Plotting load curve
23  T=[0,1,2,3,4,5,6];//Slots
24  L=[L1,L2,L3,L4,L5,L6,L7];//MW
25  plot(T,L)
26  ylabel('Load(MW)');
27  xlabel('0-1: 12-5am 1-2: 5-9am 2-3: 9-6pm 3-4: 6-8pm
        4-5:8-10pm 5-6 :10-12pm');
28  title('Chronological Load Curve');
```

Scilab code Exa 1.9 Load duration curve and Mass curve

```
1  //exa 1.9
2  clc;clear;close;
3  format('v',6);
4  L1=50;//MW//Initial
5  t1=5;//hours
6  L2=50;//MW//5am
7  t2=4;//hours
8  L3=100;//MW//9am
9  t3=9;//hours
10 L4=100;//MW//6pm
11 t4=2;//hours
```

```
12  L5 =150; //MW//8pm
13  t5 =2; // hours
14  L6 =80; //MW//10pm
15  t6 =2; // hours
16  L7 =50; //MW
17  //Load Duration Curve
18  l1=L5; //Mw
19  l2=L4; //MW
20  l3=L1; //MW
21  L=[l1,l2,l2,l3,l3]
22  T=0:6:24; //Duration in hours
23  subplot(2,1,1)
24  plot(T,L)
25  ylabel('Load(MW)');
26  xlabel('Hours');
27  title('Load Duration Curve');
28  //Energy Consumed
29  //Upto 5am
30  t1=5; // hours
31  E1=L1*t1; //MWh
32  //Upto 9am
33  t2=4; // hours
34  E2=E1+L2*t2; //MWh
35  //Upto 6pm
36  t3=9; // hours
37  E3=E2+L3*t3; //MWh
38  //Upto 10pm
39  t4=4; // hours
40  E4=E3+L4*t4; //MWh
41  //Upto 12pm
42  t4=2; // hours
43  E4=E3+L4*t4; //MWh
44  //Plotting Mass curve
45  T=[0,1,2,3,4]; //MW
46  E=[0,E1,E2,E3,E4]; //Mwh
47  subplot(2,1,2)
48  plot(T,E)
49  ylabel('Energy(MWh)');
```

```
50  xlabel('0−1: 12−5am 1−2: 5−9am 2−3: 9−6pm 3−4: 6−10
       pm above4: 10−12pm');
51  title('Mass Curve');
```

Scilab code Exa 1.10 Station Capacity and Reserve capacity

```
1  //exa 1.10
2  clc;clear;close;
3  format('v',6);
4  E=438*10^4;//kWh
5  LF=20;//% annual
6  CF=15;//%//Capacity Factor
7  Lmax=E/(LF/100)/24/365;//kW
8  Lmax=Lmax/1000;//MW
9  C=Lmax/CF*LF;//MW//Plant Capacity
10 disp(C,"Plant Capacity(MW): ");
11 RC=C-Lmax;//MW//Reserve Capacity
12 disp(RC,"Reserve Capacity(MW) : ");
```

Scilab code Exa 1.11 Maximum demand and annual energy supplied

```
1  //exa 1.11
2  clc;clear;close;
3  format('v',7);
4  L1=10000;//kW
5  L2=6000;//kW
6  L3=8000;//kW
7  L4=7000;//kW
8  df=1.5;//diversity factor
9  LF=65;//%//Load Factor
10 Dinc=60;//%//Increase in maximum demand
11 L=L1+L2+L3+L4;//kW//Sum
12 L=L/1000;//MW
```

15

```
13  Dmax=L/df;//MW
14  disp(Dmax,"Maximum demand on station(MWh)");
15  E=Dmax*365*24*LF/100;//MWh//Annual Energy
16  format('v',9);
17  disp(E,"Annual Energy Supplied(MWh)");
18  Din_max=Dinc/100*Dmax;//MW
19  format('v',7);
20  C=Dmax+Din_max;//MW
21  disp(C,"Installed Capacity(MW)")
```

Scilab code Exa 1.12 `Weekly Load Factor`

```
 1  //exa 1.12
 2  clc;clear;close;
 3  format('v',5);
 4  //Arranging data for Load Duration Curve
 5  //week days 5-9pm load
 6  L1=350;//MW
 7  t1=4*5;//hours
 8  //week days 8-12am & 1-5pm load
 9  L2=250;//MW
10  t2=t1+8*5;//hours
11  //saturday & sunday 5-9pm load
12  L3=200;//MW
13  t3=t2+4*2;//hours
14  //All days 150MW load
15  L4=150;//MW
16  t4=t3+6*5+15*2;//hours
17  //All days 100MW load
18  L5=100;//MW
19  t5=t4+6*5+5*2;//hours
20  A=31600;//Total Load Curve Area
21  LF=A/L1/24/7*100;//%//Weekly load factor
22  disp(LF,"Weekly Load factor(%)");
23  disp("Load Duration Curve is shown in figure.");
```

```
24  //Load  Duration  Curve
25  L=[L1  L2  L3  L4  L5];//MW
26  T=[t1  t2  t3  t4  t5];//hours
27  plot2d2(T,L);
28  xtitle('Load  Duration  Curve','Time(Hours)','Load(MW
        )');
```

Scilab code Exa 1.13 Annual Load factor

```
1  //exa  1.13
2  clc;clear;close;
3  format('v',7);
4  LF=0.825;//Daily  Load  Factor
5  ratio1=0.87;//daily  peak  load  to  monthly  peak  load
6  ratio2=0.78;//monthly  peak  load  to  annually  peak
        load
7  LF_annual=LF*ratio1*ratio2;//Annual  Load  Factor
8  disp(LF_annual,"Annual  Load  Factor  :  ");
```

Scilab code Exa 1.14 Peak Load on transformer and feeder

```
1   //exa  1.14
2   clc;clear;close;
3   format('v',5);
4   //Transformer1
5   Lm=300;//kW
6   df_m=0.6;//demand  factor
7   Lc=100;//kW//Commercial  Load
8   df_c=0.5;//demand  factor
9   //Transformer2
10  Lr2=500;//kW//Residential  Load
11  df_Lr2=0.4;//demand  factor
12  //Transformer3
```

```
13  Lr3=400;//kW
14  df_Lr3=0.5;//demand factor
15  //Diversity factors
16  df1=2.3;
17  df2=2.5;
18  df3=2;
19  DF=1.4;//Diversity factor between transformers
20  //Solution :
21  disp("Part(a)");
22  Lp1=(Lm*df_m+Lc*df_c)/df1;//kW//Peak load on
        Transformer1
23  disp(Lp1,"Peak load on Transformer1(kW)");
24  Lp2=Lr2*df_Lr2/df2;//kW//Peak load on Transformer2
25  disp(Lp2,"Peak load on Transformer2(kW)");
26  Lp3=Lr3*df_Lr3/df3;//kW//Peak load on Transformer3
27  disp(Lp3,"Peak load on Transformer3(kW)");
28  disp("Part(b)");
29  LpF=(Lp1+Lp2+Lp3)/DF;//Peak load on feeder
30  disp(LpF,"Peak load on feeder(kW)");
```

Scilab code Exa 1.16 Max Load and Load factor

```
1  //exa 1.16
2  clc;clear;close;
3  format('v',8);
4  L=[20 25 30 25 35 20];//MW
5  T=[6 4 2 4 4 4];//Hours
6  Lmax=max(L);//MW
7  disp(Lmax,"(a) Maximum demand(MW)");
8  E=L(1)*sum(T)+(L(2)-L(1))*T(2)+(L(3)-L(1))*T(3)+(L
        (4)-L(1))*T(4)+(L(5)-L(1))*T(5)+(L(6)-L(1))*T(6);
        //MWh
9  E=E*1000;//kWh
10 disp(E,"(b) Units generated per day(kWh)");
11 Lavg=E/sum(T);///kWh
```

```
12 Lavg=Lavg/1000; ///MW
13 disp(Lavg,"(c) Average Load(MW)");
14 format('v',6);
15 LF=Lavg/Lmax*100; //%
16 disp(LF,"(d) Load Factor(%)");
```

Scilab code Exa 1.17 `Real Power`

```
1 //exa 1.17
2 clc;clear;close;
3 format('v',8);
4 pf=0.8; //power factor
5 delf=1; //%//drop in frequency(delf/f)
6 //delP=-2*(sind(theta))^2*delf
7 theta=acosd(pf); //degree
8 delP_BY_delf=-2*sind(theta)^2; //increase in load wrt
     frequency
9 disp(-delP_BY_delf,"1% drop in frequency, Increased
   in Load(%)");
```

Scilab code Exa 1.18 `Total Energy generated`

```
1 //exa 1.18
2 clc;clear;close;
3 format('v',8);
4 Lmax=100; //MW
5 LF=40; //%//Load Factor
6 Lavg=Lmax*LF/100; //MW
7 E=Lavg*24*365; //MWh
8 disp(E,"Energy generated in a year(MWh)");
```

Scilab code Exa 1.19 Motor Load Change

```
1  //exa 1.19 page 25
2  clc;clear;close;
3  format('v',5);
4  V=400;//V
5  s1=0.03;//initial slip
6  delV=1;//%///Voltage Drop
7  R1=0.290;//ohm/phase
8  R2=0.15;//ohm/phase
9  X=0.7;//ohm/phase(X1+X2)
10 //V1^2*s1=V2^2*s2 for speed independent torque
11 //taking for calculating s2
12 V1=1;//V
13 V2=V1-V1*delV/100;//V
14 s2=V1^2/V2^2*s1;//slip
15 I2ByI1=sqrt([R1+R2/s1]^2+X^2)/sqrt([R1+R2/s2]^2+X^2)
       *(V2/V1)
16 delI=(I2ByI1-1)*100;//%//Current Increase
17 disp(delI,"1% drop in Voltage increases current by(%
       )");
18 //P=(R1+R2/s)*I^2
19 P2ByP1=(R1+R2/s2)/(R1+R2/s1)*I2ByI1^2;//ratio
20 delP=(1-P2ByP1)*100;//%//Power Decrease
21 format('v',4);
22 disp(delP,"1% drop in Voltage decreases power input
       by(%)");
23 //Answer in the textbook is not accurate.
```

Chapter 2

Economic Operation of Power System and Unit Commitment

Scilab code Exa 2.2 Saving per year

```
1  //exa 2.2
2  clc;clear;close;
3  format('v',8);
4  //For equal incremental cost
5  L1=125;//MW
6  L2=100;//MW
7  //For equal sharing
8  L=(L1+L2)/2;//MW
9  //Change in cost Unit 1
10 dC1=integrate('0.2*P1+30','P1',L1,L);//Rs./hour
11 //Change in cost Unit 2
12 dC2=integrate('0.15*P2+40','P2',L2,L);//Rs./hour
13 dCyearly=(dC1+dC2)*24*365;//Rs./year
14 disp(dCyearly,"Saving per year in economic load
       allocation(Rs./year)");
15 //Answer in the textbook is not accurate.
```

Scilab code Exa 2.3 `Increase in generation`

```
1  //exa 2.3
2  clc;clear;close;
3  format('v',6);
4  L=400;//MW///total load
5  delPD=50;//MW//increase in demand
6  //dC1/dP1=0.2*P1+30
7  //dC2/dP2=0.15*P2+40
8  twoC1=0.2;//from above equation
9  twoC2=0.15;//from above equation
10 delP1_by_delPD=(1/twoC1)/(1/twoC1+1/twoC2);
11 delP2_by_delPD=(1/twoC2)/(1/twoC1+1/twoC2);
12 delP1=delP1_by_delPD*delPD;//MW
13 disp(delP1,"Increase in generation of unit1(MW) : ")
       ;
14 delP2=delP2_by_delPD*delPD;//MW
15 disp(delP2,"Increase in generation of unit2(MW) : ")
       ;
16 format('v',7);
17 P1=L/2+delP1;//load on unit 1
18 disp(P1,"Total load on unit1(MW) : ");
19 P2=L/2+delP2;//load on unit 2
20 disp(P2,"Total load on unit2(MW) : ");
21 format('v',6);
22 disp("Checking incremental cost :");
23 dC1_by_dP1=0.2*P1+30;//Rs./MWh
24 disp(dC1_by_dP1,"Incremental cost of unit 1(Rs./MWh)
       : ");
25 dC2_by_dP2=0.2*P2+30;//Rs./MWh
26 disp(dC2_by_dP2,"Incremental cost of unit 2(Rs./MWh)
       : ");
27 disp("Conclusion : Cost are same(Approximately).");
28 //Note : Values calculated in the book are slightly
       wrong because of accuracy in calculation as
       compared to scilab accuracy.
```

Scilab code Exa 2.5 Loss Coefficient and Transmission Loss

```
1  //exa 2.5
2  clc;clear;close;
3  format('v',8);
4  I1=0.8;//p.u.
5  I2=1;//p.u.
6  Za=0.04+%i*0.12;//p.u.
7  Zb=0.03+%i*0.1;//p.u.
8  Zc=0.03+%i*0.12;//p.u.
9  V=1;//p.u.
10 //Solution :
11 V1=V+(I1+I2)*Za+I1*(Zb);//p.u.
12 V2=V+(I1+I2)*Za+I2*(Zc);//p.u.
13 P1=real(I1*V1);//p.u.
14 P2=real(I2*V2);//p.u.
15 fi1=atan(imag(V1),real(V1));
16 fi2=atan(imag(V2),real(V2));
17 disp("Loss Coefficients are : ")
18 B11=[real(Za)+real(Zb)]/[abs(V1)^2*cos(fi1)^2];//p.u
      .
19 disp(B11,"B11(p.u.) : ");
20 B22=[real(Za)+real(Zc)]/[abs(V2)^2*cos(fi2)^2];//p.u
      .
21 disp(B22,"B22(p.u.) : ");
22 B12=[real(Za)]/[abs(V1)*abs(V2)*cos(fi1)*cos(fi2)];
      //p.u.
23 disp(B12,"B12(p.u.) : ");
24 PL=P1^2*B11+P2^2*B22+2*P1*P2*B12;//p.u.
25 format('v',10);
26 disp(PL,"Transmission Loss(p.u.) : ");
27 //Note : Values calculated in the book are slightly
      wrong because of accuracy in calculation as
      compared to scilab accuracy.
```

Scilab code Exa 2.7 Loss Formula Coefficients

```scilab
1  //exa 2.7
2  clc;clear;close;
3  format('v',8);
4  Za=0.03+%i*0.09;//p.u.
5  Ia=1.5-%i*0.4;//p.u.
6  Zb=0.10+%i*0.30;//p.u.
7  Ib=0.5-%i*0.2;//p.u.
8  Zc=0.03+%i*0.09;//p.u.
9  Ic=1-%i*0.1;//p.u.
10 Zd=0.04+%i*0.12;//p.u.
11 Id=1-%i*0.2;//p.u.
12 Ze=0.04+%i*0.12;//p.u.
13 Ie=1.5-%i*0.3;//p.u.
14 V=1;//p.u.
15 base=100;//MVA
16 //Solution
17 //Currents of load
18 IL1=0.4;//p.u.
19 IL2=0.6;//p.u.
20 //Current distribution factors :
21 Na1=1;Na2=0;
22 Nb1=0.6;Nb2=-0.4;
23 Nc1=0;Nc2=1;
24 Nd1=0.4;Nd2=0.4;
25 Ne1=0.6;Ne2=0.6;
26 //Bus Voltages
27 V1=V+Ia*Za;//p.u.
28 V2=V-Ib*Zb+Ic*Zc;//p.u.
29 //Phase Angles
30 theta1=atand(imag(Ia),real(Ia));//degree
31 theta2=atand(imag(Ic),real(Ic));//degree
32 //Power Factors :
```

24

```scilab
33 cos_fi1=cosd(atand(imag(V1),real(V1))-theta1);// 
      source 1 power factor
34 cos_fi2=cosd(atand(imag(V2),real(V2))-theta2);// 
      source 2 power factor
35 disp("Loss formula Coefficients in p.u. :")
36 B11=[Na1^2*real(Za)+Nb1^2*real(Zb)+Nc1^2*real(Zc)+
      Nd1^2*real(Zd)+Ne1^2*real(Ze)]/[abs(V1)^2*cos_fi1
      ];//p.u.
37 disp(B11,"B11(p.u) : ");
38 format('v',7);
39 B22=[Na2^2*real(Za)+Nb2^2*real(Zb)+Nc2^2*real(Zc)+
      Nd2^2*real(Zd)+Ne2^2*real(Ze)]/[abs(V2)^2*cos_fi2
      ];//p.u.
40 disp(B22,"B22(p.u) : ");
41 B12=[Na1*Na2*real(Za)+Nb1*Nb2*real(Zb)+Nc1*Nc2*real(
      Zc)+Nd1*Nd2*real(Zd)+Ne1*Ne2*real(Zc)]/[abs(V1)*
      abs(V2)*cos_fi1*cos_fi2*[cosd(theta1-theta2)]];//
      p.u.
42 disp(B12,"B12(p.u) : ");
43 //Converting p.u. to actual value
44 format('v',10);
45 disp("Loss formula Coefficients in MW^-1 :")
46 B11=B11/base;//MW^-1
47 disp(B11,"B11(MW^-1) : ");
48 format('v',9);
49 B22=B22/base;//MW^-1
50 disp(B22,"B22(MW^-1) : ");
51 B12=B12/base;//MW^-1
52 disp(B12,"B12(MW^-1) : ");
53 //Note : Values calculated in the book are slightly
      wrong because of accuracy in calculation as
      compared to scilab accuracy.
```

Scilab code Exa 2.8 Required generationa at each plant

```
1  //exa 2.8
2  clc ; clear ; close ;
3  format ('v' ,8) ;
4  //dC1/dP1=0.2*P1+22;//Rs./MWh
5  //dC2/dP2=0.15*P2+30;//Rs./MWh
6  B22 =0; B12 =0; //Because  Loss  is  independent  wrt  P2
7  P1 =100; //MW
8  PL =15; //MW
9  B11 = PL / P1 ^2; //MW^ -1
10 L1 =1/[1 -0.003* P1 ]; //Penalty  Factor  plant  1
11 L2 =1; //Penalty  Factor  of  plant  2
12 lambda =60;
13 //lambda=dC1/dP1*L1=dC2/dP2*L2
14 //dC1/dP1*L1=dC2/dP2*L2
15 P2 =((0.2* P1 +22) * L1 -30) /0.15; //MW
16 P = P1 + P2 - B11 * P1 ^2; //MW//Total  Load
17 disp (P1 ,"Required  generation  at  plant1 (MW) ") ;
18 disp (P2 ,"Required  generation  at  plant2 (MW) ") ;
19 disp (P ,"Total  Load (MW) ") ;
```

Scilab code Exa 2.9 Saving in Rs per hour

```
1  //exa 2.9
2  clc ; clear ; close ;
3  format ('v' ,6) ;
4  //dC1/dP1=0.2*P1+22;//Rs./MWh
5  //dC2/dP2=0.15*P2+30;//Rs./MWh
6  B22 =0; B12 =0; //Because  Loss  is  independent  wrt  P2
7  P1 =100; //MW
8  PL =15; //MW
9  B11 = PL / P1 ^2; //MW^ -1
10 L1 =1/[1 -0.003* P1 ]; //Penalty  Factor  plant  1
11 L2 =1; //Penalty  Factor  of  plant  2
12 lambda =60;
13 //lambda=dC1/dP1*L1=dC2/dP2*L2
```

```
14  //dC1/dP1*L1=dC2/dP2*L2
15  P2=((0.2*P1+22)*L1-30)/0.15;//MW
16  P=P1+P2-B11*P1^2;//MW//Total Load
17  //dC1/dP1=dC2/dP2; neglecting transmission loss
18  clear('P2');//for recalculation
19  //0.2*P1-0.15*P2-8=0;///eqn(1)
20  //P1=0.75*P2+40;//P1+P2-B11*P1^2-P=0;//eqn(2)
21  //1.75*P2-B11*P1^2=P-40
22  Eqn=[-B11 1.75 40-P];
23  P2=roots(Eqn);
24  P2=P2(2);//MW//neglecting higher value
25  P1=0.75*P2+40;//MW
26  dC1=integrate('0.2*P+22','P',100,P1);//Rs.//
        Additional Cost plant1
27  dC2=integrate('0.15*P+30','P',200,P2);//Rs.//
        Decreased Cost  plant2
28  dC=dC1+dC2;//Rs./hour//Net change in cost
29  disp(dC,"Taking transmission loss in account, Net
        saving per hour in fuel cost(Rs,/hour)");
30  //Note : Values calculated in the book are slightly
        wrong because of accuracy in calculation as
        compared to scilab accuracy.
```

Scilab code Exa 2.10 Transmission Loss and Recieved Power

```
1   //exa 2.10
2   clc;clear;close;
3   format('v',5);
4   B11=0.001;//MW^-1
5   B22=0.0024;//MW^-1
6   B12=-0.0005;//MW^-1
7   //dC1/dP1=0.8*P1+16;//Rs./MWh
8   //dC2/dP2=0.08*P2+12;//Rs./MWh
9   lambda=20;
10  //Iterations for calculating value
```

```
11  P1(1)=0;
12  P2=0;
13  for i=2:1:10
14      P1(i)=(0.2+0.001*P2(i-1))/0.006;
15      P2(i)=(0.4+0.001*P1(i))/0.0088;
16      if  P1(i)==P1(i-1) then
17  break;
18      end
19  end
20  P1=P1(i);//MW
21  disp(P1,"Generation P1(MW) : ");
22  P2=P2(i);//MW
23  disp(P2,"Generation P2(MW) : ");
24  format('v',4);
25  PL=B11*P1^2+2*B12*P1*P2+B22*P2^2;//MW
26  disp(PL,"Transmission Loss(MW) : ");
27  format('v',5);
28  Pr=P1+P2-PL;//MW
29  disp(Pr,"Received Power(MW) : ");
```

Scilab code Exa 2.11 Cost Characteristics

```
1  //exa 2.11
2  clc;clear;close;
3  format('v',7);
4  //C1=561+7.92*P1+0.001562*P1^2;//Rs./hour
5  //C2=310+7.85*P2+0.00194*P2^2;//Rs./hour
6  a1=561;a2=310;
7  b1=7.92;b2=7.85;
8  c1=0.001562;c2=0.00194;
9  ce=c1*c2/(c1+c2);
10 be=ce*(b1/c1+b2/c2);
11 ae=a1-b1^2/4/c1+a2-b2^2/4/c2+be^2/4/ce;
12 disp("Coefficients are : ");
13 disp("ae = "+string(ae)+" & be = "+string(be));
```

```
14  format ('v',10);
15  disp (ce,"ce = ")
16  PT=poly (0,'PT');
17  disp ("Cost Characteristics : ")
18  disp ("CT=870.753+7.8888*PT+0.0008653*PT^2");
```

Scilab code Exa 2.12 `Daily Operating Schedule`

```
1  //exa 2.12
2  clc;clear;close;
3  format ('v',7);
4  //C1=7700+52.8*P1+5.5*10^-3*P1^2;//Rs./hour
5  //C2=2500+15*P2+0.05*P2^2;//Rs./hour
6  a1=7700;a2=2500;
7  b1=52.8;b2=15;
8  c1=5.5*10^-3;c2=0.05;
9  P1=poly (0,'P1');
10  P2=poly (0,'P2');
11  dC1bydP1=52.8+2*5.5*10^-3*P1;
12  dC2bydP2=15+2*0.05*P2;
13  disp ("For 1200 MW Load :");
14  P=1200;//MW
15  //Let loads of unit are P1 & 1200-P1
16  //Economical Loading dC1/dP1=dC2/dP2
17  eqn=52.8+2*5.5*10^-3*P1-15-2*0.05*(1200-P1);
18  P1=roots (eqn);//MW
19  P2=1200-P1;//MW
20  disp (P1,"P1(MW) : ");
21  disp (P2,"P2(MW) : ");
22  disp ("For 900 MW Load :");
23  P=900;//MW
24  clear ('P1','P2');
25  P1=poly (0,'P1');
26  P2=poly (0,'P2');
27  //Let loads of unit are P1 & 900-P1
```

```scilab
28  //Economical Loading dC1/dP1=dC2/dP2
29  eqn=52.8+2*5.5*10^-3*P1-15-2*0.05*(900-P1);
30  P1=roots(eqn);//MW
31  P2=900-P1;//MW
32  disp(P1,"P1(MW) : ");
33  disp(P2,"P2(MW) : ");
34  disp("For 500 MW Load :");
35  P=500;//MW
36  clear('P1','P2');
37  P1=poly(0,'P1');
38  P2=poly(0,'P2');
39  //Let loads of unit are P1 & 500-P1
40  //Economical Loading dC1/dP1=dC2/dP2
41  eqn=52.8+2*5.5*10^-3*P1-15-2*0.05*(500-P1);
42  P1=roots(eqn);//MW
43  P2=500-P1;//MW
44  //Minimum load is 200MW
45  if P1<200 then
46      P2=P1+P2
47      P1=0;
48  end
49  disp(P1,"P1(MW) : ");
50  disp(P2,"P2(MW) : ");
51  format('v',10);
52  C=(2500+15*P2+0.05*P2^2)*10;//Rs.//Operating cost
        for 10 hour
53  disp(C,"Operating cost for 10 hour(Rs.)");
54  disp("Other option : ");
55  P1=200;//MW
56  P2=300;//MW
57  disp(P1,"P1(MW) : ");
58  disp(P2,"P2(MW) : ");
59  C1=7700+52.8*P1+5.5*10^-3*P1^2;//Rs./hour
60  C2=2500+15*P2+0.05*P2^2;//Rs./hour
61  C=10*(C1+C2);//Rs.//Operating cost for 10 hour
62  disp(C,"Operating cost for 10 hour(Rs.)");
```

Scilab code Exa 2.13 Cost of generation

```
1  //exa 2.13
2  clc;clear;close;
3  format('v',10);
4  //C1=2000+20*P1+0.05*P1^2;//Rs./hour
5  //C2=2750+26*P2+0.03091*P2^2;//Rs./hour
6  P1=350;//MW
7  P2=550;//MW
8  C1=2000+20*P1+0.05*P1^2;//Rs./hour
9  C2=2750+26*P2+0.03091*P2^2;//Rs./hour
10 C=C1+C2;//Rs./hour
11 disp(C,"(a) Total Cost(Rs./hour)");
12 P=P1+P2;//MW//Total Load
13 P1=poly(0,'P1');
14 P2=poly(0,'P2');
15 dC1bydP1=20+2*0.05*P1;
16 dC2bydP2=26+2*0.03091*P2;
17 disp("(b) For Economic Scheduling")
18 format('v',7);
19 //dC1/dP1=dC2/dP2 for economic sheduling
20 //Let loads of unit are P1 & P-P1
21 eqn=20+2*0.05*P1-26-2*0.03091*(P-P1);
22 P1=roots(eqn);//MW
23 P2=P-P1;//MW
24 disp(P2,P1,"Loads P1 & P2 in MW are : ");
25 C1=2000+20*P1+0.05*P1^2;//Rs./hour
26 C2=2750+26*P2+0.03091*P2^2;//Rs./hour
27 Cnew=C1+C2;//Rs./hour
28 disp(Cnew,"Total Cost(Rs./hour)");
29 saving=C-Cnew;//Rs./hour
30 disp(saving,"Total saving(Rs./hour)");
31 format('v',5);
32 Lt=P1-350;//MW//Tie line load
```

```
33  disp (Lt ,"Tie line load from Plant1 to Plant2 (MW) : "
        );
```

Scilab code Exa 2.14 Extra Ooperating Cost

```
1  // exa  2.14
2  clc ; clear ; close ;
3  format ( 'v ' ,7) ;
4  //C=5000+450*P+0.5*P^2; //Rs./ hour
5  e1 =+2; //%// error
6  e2 = -2; //%// error
7  P =200; //MW// Total Load
8  // Considering error
9  P1 = poly (0 , 'P1 ') ;
10  P2 = poly (0 , 'P2 ') ;
11  C1 =(5000+450* P +0.5* P1 ^2) *0.98; //Rs./ hour
12  C2 =(5000+450* P +0.5* P2 ^2) *1.02; //Rs./ hour
13  // Let loads of unit are P1 & P-P1
14  //dC1/dP1=dC2/dP2 for economic sheduling
15  eqn =450*0.98+2*0.5* P1 *0.98 -450*1.02 -2*0.5*( P - P1 )
        *1.02;
16  P1 = roots ( eqn ) ; //MW
17  P2 =P - P1 ; //MW
18  // if no instrumention error
19  C1 =(5000+450* P1 +0.5* P1 ^2) *0.98; //Rs./ hour
20  C2 =(5000+450* P2 +0.5* P2 ^2) *1.02; //Rs./ hour
21  C =C1 + C2 ; //Rs./ hour
22  //Due to intrumentation error
23  P1 =P /2; //MW
24  P2 =P /2; //MW
25  C1 =(5000+450* P1 +0.5* P1 ^2) *0.98; //Rs./ hour
26  C2 =(5000+450* P2 +0.5* P2 ^2) *1.02; //Rs./ hour
27  Cerr = C1 + C2 ; //Rs./ hour
28  Cextra = Cerr -C ; //Rs,/ hour
29  disp ( Cextra ,"Extra operating cost (Rs./ hour )") ;
```

Scilab code Exa 2.15 Find Optimum Scheduling

```
1  //exa 2.15
2  clc;clear;close;
3  format('v',7);
4  P1=poly(0,'P1');
5  P2=poly(0,'P2');
6  P3=poly(0,'P3');
7  Q1=0.002*P1^2+0.86*P1+20;//tons/hour
8  Q2=0.004*P2^2+1.08*P2+20;//tons/hour
9  Q3=0.0028*P3^2+0.64*P3+36;//tons/hour
10 Pmax=120;//MW
11 Pmin=36;//MW
12 P=200;//MW
13 C=500;//Rs./ton
14 //C1=C*Q1;C2=C*Q2;C3=C*Q3;//Rs./ton
15 dC1bydP1=2*P1+430;//Rs./hour
16 dC2bydP2=4*P2+540;//Rs./hour
17 dC3bydP3=2.8*P3+320;//Rs./hour
18 //P1+P2+P3=P
19 A1=[1 1 1];//Coefficient Matrix
20 B1=[P];//Coefficient Matrix
21 //For minimal cost above 3 equation should be equal
22 //eqn1=2*P1-4*P2+430-540;
23 //eqn2=4*P2-2.8*P3-320+540;
24 A2=[0 4 -2.8];//Coefficient Matrix
25 B2=[-540+320];//Coefficient Matrix
26 //eqn3=-2*P1+2.8*P3+320-430;
27 A3=[-2 0 2.8];//Coefficient Matrix
28 B3=[430-320];//Coefficient Matrix
29 //solving by matrix method
30 A=[A1;A2;A3];//Coefficient Matrix
31 B=[B1;B2;B3];//Coefficient Matrix
32 X=A^-1*B;//Solution Matrix
```

```
33  P1=X(1);//MW
34  P2=X(2);//MW
35  P3=X(3);//MW
36  Pmax=120;//MW
37  Pmin=36;//MW
38  if P2<Pmin then
39      P2=Pmin;//MW
40  end;
41  //P1+P3=P-P2//eqn(4)
42  A1=[1 1];//Coefficient Matrix
43  B1=[P-P2];//Coefficient Matrix
44  //eqn3=-2*P1+2.8*P3+320-430;
45  A2=[-2 2.8];//Coefficient Matrix
46  B2=[430-320];//Coefficient Matrix
47  //solving by matrix method
48  A=[A1;A2];//Coefficient Matrix
49  B=[B1;B2];//Coefficient Matrix
50  X=A^-1*B;//Solution Matrix
51  P1=X(1);//MW
52  P3=X(2);//MW
53  disp("According to optimum scheduling, Load
         distriution is :");
54  disp(P1,"P1(MW) : ");
55  disp(P2,"P2(MW) : ");
56  disp(P3,"P3(MW) : ");
```

Scilab code Exa 2.16 Heat inputs and savings

```
1  //exa 2.16
2  clc;clear;close;
3  format('v',11);
4  L=30;//MW
5  //I=(32+32*L+1.68*L^2)*10^5;
6  t1=18;///hours
7  t2=6;///hours
```

```
 8  // Full load 18 hours
 9  I1 =(32+32*L+1.68*L^2)*10^5*t1;//kJ
10  // Half load 6 hours
11  I2 =(32+32*L/2+1.68*(L/2)^2)*10^5*t2
12  I = I1+I2;//kJ
13  disp(I,"(a) Heat input per day(kJ)");
14  E=L*t1+L/2*t2;//MWh///Energy produced in 24 hours
15  Lu=E/(t1+t2);//MW
16  Inew =(32+32*Lu+1.68*Lu^2)*10^5*(t1+t2);//kJ
17  saving=I-Inew;///kJ
18  saving=saving/(E*1000);//kJ/kWh
19  disp(saving,"(b) Saving in heat per kWh of energy(kJ
        /kWh) : ");
```

Scilab code Exa 2.17 `Find Optimum Scheduling`

```
 1  // exa 2.17
 2  clc; clear; close;
 3  format('v',7);
 4  P=800;//MW(Total Load)
 5  // Using Variable for Cost Curve Equation
 6  P1=poly(0,'P1');P2=poly(0,'P2');P3=poly(0,'P3');
 7  // Cost Curve Equation
 8  C1 =450+6.5*P1+0.0013*P1^2;//Rs./hour
 9  C2 =300+7.8*P2+0.0019*P2^2;//Rs./hour
10  C3 =80+8.1*P3+0.005*P3^2;//Rs./hour
11  // Part(a) is not computational
12  // Part (b)
13  dC1BydP1 =6.5+2*0.0013*P1;//Rs./MWh///eqn(1)
14  dC2BydP2 =7.8+2*0.0019*P2;//Rs./MWh///eqn(2)
15  dC3BydP3 =8.1+2*0.005*P3;//Rs./MWh///eqn(3)
16  // P1+P2+P3=P;//MW///eqn(4)
17  A1 =[1 1 1];// Coefficient Matrix
18  B1 =[800];// Coefficient Matrix
19  // Equating eqn(1) & (2)
```

```
20  A2=[2*0.0013 -2*0.0019 0];//Coefficient Matrix
21  B2=[7.8-6.5];//Coefficient Matrix
22  //Equating eqn(2) & (3)
23  A3=[0 2*0.0019 -2*0.005];//Coefficient Matrix
24  B3=[8.1-7.8];//Coefficient Matrix
25  //Solution By Matrix method
26  A=[A1;A2;A3];//Coefficient Matrix
27  B=[B1;B2;B3];//Coefficient Matrix
28  X=A^-1*B;//Solution Matrix
29  P1=X(1);//MW
30  P2=X(2);//MW
31  P3=X(3);//MW
32  disp("(b) According to optimum scheduling, Load
         distriution is :");
33  disp(P1,"P1(MW) : ");
34  disp(P2,"P2(MW) : ");
35  disp(P3,"P3(MW) : ");
36  //Part(c)
37  disp("(c) Optimum scheduling : ");
38  P1max=600;//MW
39  P1min=100;//MW
40  P2max=400;//MW
41  P2min=50;//MW
42  P3max=200;//MW
43  P3min=50;//MW
44  if P2<P2max&P2>P2min then
45      disp("P2 is within maximum and minimum limits.")
            ;
46      P1=P1max;//MW
47      P3=P3min;//MW
48      P2=P-P1-P3;//MW
49  end;
50  //Lambda=dC2/dP2 as P2 is niether maximum limit nor
        minimum limit.
51  dC2BydP2=7.8+2*0.0019*P2;//Rs./MWh
52  lambda=dC2BydP2;//Rs./MWh
53  dC1BydP1=6.5+2*0.0013*P1;//Rs./MWh
54  dC3BydP3=8.1+2*0.005*P3;//Rs./MWh
```

```scilab
55  if dC1BydP1 < lambda then
56      disp("Condition for P1 satisfied.");
57  end;
58  if dC3BydP3 > lambda then
59      disp("Condition for P3 satisfied.");
60  end;
61  disp("Load distribution is : ");
62  disp(P1,"P1(MW) : ");
63  disp(P2,"P2(MW) : ");
64  disp(P3,"P3(MW) : ");
```

Scilab code Exa 2.18 Transmission Loss

```scilab
1   //exa 2.18
2   clc;clear;close;
3   format('v',6);
4   Bmn=[0.0676 0.00953 -0.00507
5   0.00953 0.0521 0.00901
6   -0.00507 0.00901 0.0294];//Loss Coefficient
7   Bno=[-0.0766;0.00342;0.0189];//Loss Coefficient
8   Boo=0.04357;//Loss Coefficient
9   P1=107.9;//MW
10  P2=50;//MW
11  P3=60;//MW
12  //solution :
13  PL=[P1 P2 P3]*Bmn+[P1 P2 P3]*Bno+Boo;//MW
14  PL=sum(-PL);//MW
15  disp(PL,"Transmission Loss(MW)");
16  //Note : Values calculated in the book are slightly
        wrong because of accuracy in calculation as
        compared to scilab accuracy.
```

Scilab code Exa 2.19 Find Load Distribution

```
1  //exa 2.19
2  clc;clear;close;
3  format('v',6);
4  //lambda1=0.1*P1+20;//Rs./MWh
5  //lambda2=0.12*P2+16;//Rs./MWh
6  P=180;//MW
7  //Let loads are P1 & P-P1
8  //Economical loading lambda1=lambda2
9  P1=poly(0,'P1');P2=poly(0,'P2');
10 eqn=0.1*P1+20-0.12*(P-P1)-16;
11 P1=roots(eqn);//MW
12 P2=P-P1;//MW
13 disp(P1,"Load P1(MW) : ");
14 disp(P2,"Load P2(MW) : ");
```

Scilab code Exa 2.20 Find the load division

```
1  //exa 2.20
2  clc;clear;close;
3  format('v',6);
4  //F1=0.004*P1^2+2*P1+80;//Rs./hr
5  //F2=0.006*P2^2+1.5*P2+100;//Rs./hr
6  P=250;//MW
7  P1=poly(0,'P1');P2=poly(0,'P2');
8  dF1bydP1=2*0.004*P1+2;
9  dF2bydP2=2*0.006*P2+1.5;
10 //Let loads are P1 & P-P1
11 //Economical loading lambda1=lambda2
12 eqn=2*0.004*P1+2-2*0.006*(P-P1)-1.5;
13 P1=roots(eqn);//MW
14 P2=P-P1;//MW
15 disp(P1,"Load P1(MW) : ");
16 disp(P2,"Load P2(MW) : ");
```

Scilab code Exa 2.21 `Minimum cost of generation`

```
1  //exa 2.21
2  clc;clear;close;
3  format('v',8);
4  //F1=(8*P1+0.024*P1^2+80)*10^6;//Btu./hr
5  //F2=(6*P2+0.04*P2^2+120)*10^6;//Btu./hr
6  Pmax=100;//MW
7  Pmin=10;//MW
8  C=2.5;//Rs./million Btu
9  //C1=2.5*F1/10^6
10 //C2=2.5*F2/10^6
11 //For Maximum Load of 100 MW
12 P1=poly(0,'P1');P2=poly(0,'P2');
13 dC1bydP1=8*2.5+2.5*2*0.024*P1;
14 dC2bydP2=6*2.5+2.5*2*0.04*P2;
15 //Let loads are P1 & Pmax-P1
16 //Economical loading lambda1=lambda2
17 eqn=8*2.5+2.5*2*0.024*P1-6*2.5-2.5*2*0.04*(Pmax-P1);
18 P1=roots(eqn);//MW
19 P2=Pmax-P1;//MW
20 C1=2.5*((8*P1+0.024*P1^2+80)*10^6)/10^6;//Rs./hour
21 C2=2.5*((6*P2+0.04*P2^2+120)*10^6)/10^6;//Rs./hour
22 C100=(C1+C2)*12;//Rs.(Total cost of 12 hours on 100
       MW load)
23 //For Maximum load of 50 MW
24 //Let loads are P1 & Pmax-P1
25 //Economical loading : lambda1=lambda2
26 Pmax1=50;//MW
27 clear('P1','P2');
28 P1=poly(0,'P1');P2=poly(0,'P2');
29 eqn=8*2.5+2.5*2*0.024*P1-6*2.5-2.5*2*0.04*(Pmax1-P1)
       ;
30 P1=roots(eqn);//MW
```

```
31  P2=Pmax1-P1;//MW
32  C1=2.5*((8*P1+0.024*P1^2+80)*10^6)/10^6;//Rs./hour
33  C2=2.5*((6*P2+0.04*P2^2+120)*10^6)/10^6;//Rs./hour
34  C50=(C1+C2)*12;//Rs.(Total cost of 12 hours on 50MW
      load)
35  C=C100+C50;//Rs.(Total cost for 24 hours)
36  disp(C,"Minimum total cost for 24 hours(Rs.) : ");
37  E=(Pmax*12+Pmax1*12)*10^3;//kWh
38  //Operating cost per unit energy
39  Co=C/E;//Rs./kWh
40  disp(Co,"Operating cost per unit energy(Rs./kWh) : "
      );
41  //Answer is wrong in the textbook. Calculation
      mistake in energy generation calculation & Cost
      calculation.
```

Scilab code Exa 2.22 Find Optimum Scheduling

```
1  //exa 2.22
2  clc;clear;close;
3  format('v',10);
4  //F1=0.05*P1^2+21.5*P1+800;//Rs./hr
5  //F2=0.1*P2^2+27*P2+500;//Rs./hr
6  //F3=0.07*P3^2+16*P3+900;//Rs./hr
7  PT=200;//MW
8  Pmax=120;//MW
9  Pmin=39;//MW
10  //coefficients :
11  c1=0.05;c2=0.1;c3=0.07;
12  b1=21.5;b2=27;b3=16;
13  a1=800;a2=500;a3=900;
14  lambda=(1/2*[b1/c1+b2/c2+b3/c3]+PT)/[1/2*[1/c1+1/c2
      +1/c3]];
15  //Economical loading dF1/dP1=dF2/dP2=dF3/dP3
16  P1=poly(0,'P1');P2=poly(0,'P2');P3=poly(0,'P3');
```

```
17  dF1bydP1=2*0.05*P1+21.5;
18  dF2bydP2=2*0.1*P2+27;
19  dF2bydP3=2*0.07*P3+16;
20  //Solving equation :
21  A=[2*0.05 0 0;0 2*0.1 0;0 0 2*0.07];
22  B=[lambda-21.5;lambda-27;lambda-16];
23  X=A^-1*B;
24  P1=X(1);//MW
25  P2=X(2);//MW
26  P3=X(3);//MW
27  if P2<Pmin then
28      P2=Pmin;
29  end
30  P1plusP3=PT-P2;//MW
31  //dF1/dP1=dF3/dP3
32  //Let loads are P1 & P1plusP3-P1
33  clear('P1','P3');
34  P1=poly(0,'P1');P3=poly(0,'P3');
35   eqn=2*0.05*P1+21.5-2*0.07*(P1plusP3-P1)-16;
36   P1=roots(eqn);//MW
37   P3=P1plusP3-P1;//MW
38   disp("Optimum scheduling :");
39   disp(P3,P2,P1,"Loads P1, P2 & P3 in MW are :");
40   F1=0.05*P1^2+21.5*P1+800;//Rs./hr
41  F2=0.1*P2^2+27*P2+500;//Rs./hr
42  F3=0.07*P3^2+16*P3+900;//Rs./hr
43  C=F1+F2+F3;//Rs/hour
44  disp(C,"For this schedule, total cost per hour(Rs./
        hour)");
```

Scilab code Exa 2.23 Generation schedule and load demand

```
1  //exa 2.23
2  clc;clear;close;
3  format('v',7);
```

```
4  //dF1/dP1=0.025*P1+15;//
5  //dF2/dP2=0.05*P2+20;//
6  PL=15.625;//MW
7  P1=125;//MW
8  lambda=24;//Rs. per MWh
9  B11=PL/P1^2;//Coefficient Loss
10 //dF2/dP2*L2=lambda
11 P2=poly(0,'P2');
12 L2=1;//penalty factor
13 eqn=(0.05*P2+20)*L2-lambda;
14 P2=roots(eqn);//MW
15 //PL=B11*P1^2
16 P1=poly(0,'P1');
17 dPLbydP1=2*B11*P1;
18 L1=1/(1-dPLbydP1);//penalty factor
19 eqn=(0.025*P1+15)-lambda/L1;
20 P1=roots(numer(eqn));//MW
21 disp(P2,P1,"Generation P1 & P2 in MW are ");
22 PL=B11*P1^2;//MW
23 LD=P1-PL+P2;//MW
24 disp(LD,"Load Demand(MW) :");
```

Scilab code Exa 2.24 Optimum Schedule and total generation

```
1  //exa 2.24
2  clc;clear;close;
3  format('v',7);
4  //dC1/dP1=0.02*P1+16;//
5  //dC2/dP2=0.04*P2+20;//
6  PL=10;//MW
7  P1=100;//MW
8  lambda=25;//Rs. per MWh
9  B11=PL/P1^2;B22=0;B12=0;//Coefficient Loss
10 //dF2/dP2*L2=lambda
11 P2=poly(0,'P2');
```

```scilab
12  L2=1;//penalty factor
13  eqn=(0.04*P2+20)*L2-lambda;
14  P2=roots(eqn);//MW
15  //PL=B11*P1^2
16  P1=poly(0,'P1');
17  dPLbydP1=2*B11*P1;
18  L1=1/(1-dPLbydP1);//penalty factor
19  eqn=(0.02*P1+16)-lambda/L1
20  P1=roots(numer(eqn));//MW
21  disp(P2,P1,"Generation P1 & P2 in MW are ")
22  PL=B11*P1^2;//MW
23  LD=P1-PL+P2;//MW
24  disp(LD,"Load Demand(MW) :");
```

Chapter 3

Hydrothermal Coordination

Scilab code Exa 3.1 MW rating

```
1  //Exa 3.1
2  clc;clear;close;
3  format('v',6);
4  head=205;//m(Mean Head)
5  A=1000;//km^2(Catchment area)
6  rf=125;//cm(Annual Rainfall)
7  a=80;//%(Available rainfall for power generation)
8  LF=75;//%(Load factor)
9  head_loss=5;//m(Head Loss)
10 Eta_turbine=0.9;//Efficiency of turbine
11 Eta_generator=0.95;//Efficiency of generator
12 //Calculation
13 WaterUsed=A*10^6*rf/100*a/100;//m^3/year(Discharge)
14 WaterUsed=WaterUsed/(365*24*60*60);//m^3/sec
15 Eff_Head=head-head_loss;//m(Effective Head)
16 P=735.5/75*WaterUsed*Eff_Head*Eta_turbine*
       Eta_generator/1000;//MW(Load of station)
17 Ppeak=P/(LF/100);//MW(Peak Load )
18 disp(Ppeak,"MW rating of station(MW)");
19 //type ot turbine
20 if head>200 then
```

```
21    disp("Pelton turbine is more suitable because
          head >200 meter.");
22 end;
```

Scilab code Exa 3.2 Capacity of hydro plant and steel plant

```
1  //Exa 3.2
2  clc;clear;close;
3  format('v',6);
4  WF=50;//m^3/sec(Water flow)
5  head=90;//m
6  LF=75;//%(Load factor)
7  Eta=90;//%(Efficiency of hydro plant)
8  L=5;//%(Transmission losses)
9  TC=350;//MW
10 hp=140;//MW//Hydro power
11 //Calculation
12 P=735.5/75*WF*head*Eta/100/1000;//MW(Power available
      )
13 Pnet=P*(100-L)/100;//MW///Net Available hydro power
14 E=Pnet*24;//MW-hours////Hydro Energy
15 disp(E,"Available hydro energy(MW-hours) : ");
16 format('v',5);
17 C1=hp/((100-L)/100);//MW//Capacity of hydro plant
18 disp(C1,"Capacity of hydro plant(MW) : ");
19 C2=TC-hp;//MW//Capacity of thermal plant
20 disp(C2,"Capacity of thermal plant(MW) : ");
```

Scilab code Exa 3.3 Water Used and operating cost

```
1  //Exa 3.3
2  clc;clear;close;
3  format('v',9);
```

```
 4  P1 =700; //MW( Load  for  14  hours )
 5  P2 =500; //MW( Load  for  10  hours )
 6  B22 =0.0005; // Loss  Coefficient
 7  t1 =14; // hour
 8  t2 =10; // hour
 9  r2 =2.5; // Rs / hour /( m ^3/ sec )
10  // Characteristics  of  units  :
11  //C1 =(24+0.02* P1 )* P1 ; // Rs ./ hour
12  //W2 =(6+0.0025* P2 )* P2 ; // m ^3/ sec
13  lambda =37.944; // Rs ./ MWh ( For  peak  load  conditions )
14  P1 =348.6; //MW( For  peak  load  conditions )
15  P2 =454.84; //MW( For  peak  load  conditions )
16  PL =103.44; //MW( For  peak  load  conditions )
17  lambda_dash =31.73; // Rs ./ MWh ( For  peak  load  conditions
       )
18  P1_dash =193.25; //MW( For  peak  off  conditions )
19  P2_dash =378.25; //MW( For  peak  off  conditions )
20  PL_dash =71.50; //MW( For  peak  off  conditions )
21  W =[(6+0.0025* P2 )* P2 * t1 +(6+0.0025* P2_dash )* P2_dash * t2
       ]*3600/10^3; // m ^3// D3ily  water  used
22  disp (W ," Daily  water  used  by  plant ( m ^3)  :  ");
23  C =(24+0.02* P1 )* P1 * t1 +(24+0.02* P1_dash )* P1_dash * t2 ; //
       Rs .
24  disp (C ," Daily  operating  cost  of  plant ( Rs .)  :  ");
```

Scilab code Exa 3.4 Load on plant and cost of water

```
 1  // Exa  3.4
 2  clc ; clear ; close ;
 3  format ( 'v ' ,7);
 4  t1 =14; // hour ( working  hour  of  hydro  station )
 5  t2 =24; // hour ( Working  hour  of  steam  station )
 6  // Characteristics  of  units  :
 7  //C =(5+8* Ps +0.05* Ps ^2) ; // Rs ./ hour
 8  //dW/dPh =30+0.05* Ph ; // m ^3/ MW- sec
```

```
9  W=500*10^6; //m^3( Water  Quantity  used )
10 Ps=250; //MW( Load  on  steam  station )
11 lambda=8+0.1*Ps; //Rs./MW-hour
12 //W=Ph*(30+0.05*Ph)*t1*3600;//
13 //0.05*Ph^2*t1*3600+Ph*30*t1*3600-W=0
14 Ph=poly(0,'Ph');
15 Ph=roots(0.05*Ph^2*t1*3600+Ph*30*t1*3600-W); //MW
16 Ph=Ph(2); //MW// Leaving  negative  root
17 disp(Ph,"Load  on  hydro  plant(MW)");
18 r=lambda/(30+0.05*Ph); //Rs./hour/(m^3/sec)
19 disp(r,"Cost  of  water  use(Rs./hour/(m^3/sec)) : ");
20 //Answer  is  slightly  differ  due  to  accuracy  in
       calculations.
```

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Chapter 4

Modelling of turbine generators and automatic controllers

Scilab code Exa 4.1 Shared load and power factor

```
1  //Exa 4.1
2  clc;clear;close;
3  format('v',8);
4  kVA=4000;//kVA//rating
5  f1_nl=50;//Hz(No load frequency of machine1)
6  f1_fl=47.5;//Hz(No load frequency of machine1)
7  f2_nl=50;//Hz(No load frequency of machine2)
8  f2_fl=48;//Hz(No load frequency of machine2)
9  L=6000;//kW(Load)
10 L1=poly(0,'L1');//Load of machine1
11 //f1_nl-(f1_nl-f1_fl)*L1/kVA=f1_nl-(f2_nl-f2_fl)*L2/
      kVA where L2=L-L1
12 L1=(f2_nl-f2_fl)*L/[(f1_nl-f1_fl)+(f2_nl-f2_fl)];//
      kW
13 L2=L-L1;//kW
14 disp("Part(a)");
15 disp(L1,"Load supplied by first machine(kW)");
16 disp(L2,"Load supplied by second machine(kW)");
17 disp("Part(b)");
```

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```
18  L2=4000;//kW//Machine2 is supplying 4000kW
19  fdrop1=f1_nl-f1_fl;//Hz(frequency drop of machine 1)
20  fdrop2=f2_nl-f2_fl;//Hz(frequency drop of machine 2)
21  L1=L2*fdrop2/fdrop1;//kW//Load supplied by machine 1
22  L=L1+L2;//kW//Total Load
23  disp(L,"Total load supplied without getting over
       loaded(kW)")
```

Scilab code Exa 4.2 `Current Power factor and emf`

```
1  //Exa 4.2
2  clc;clear;close;
3  format('v',6);
4  Lt=3000;//kW//Total Load
5  pf=0.8;//Power factor Lagging
6  I=150;//A
7  ZA=0.4+%i*12;//ohm//synchronous impedence
8  ZB=0.5+%i*10;//ohm//synchronous impedence
9  Vt=6.6;//kV//Terminal Voltage
10 L=Lt/2;//kW//Load supplied by each machine
11 LA=L;//kW
12 LB=L;//kW
13 //LB=sqrt(3)*Vt*IB*cosd(theta_B);
14 theta_B=acosd(LB/sqrt(3)/Vt/I);//degree
15 IB=I*(cosd(theta_B)-%i*sind(theta_B));//A
16 I_total=Lt/sqrt(3)/Vt/pf;//A//Total Current
17 IA_plus_IB=I_total*(0.8-%i*0.6);//A
18 IA=IA_plus_IB-IB;//A
19 cos_thetaA=real(IA)/abs(IA);//lagging power factor
20 EA=Vt/sqrt(3)+IA*ZA/1000;//kV per phase
21 del_A=atand(imag(EA)/real(EA));//degree//Load Angle
22 emf_A=abs(EA);//kV per phase//Induced emf of machine
       A
23 EB=Vt/sqrt(3)+IB*ZB/1000;//kV per phase
24 del_B=atand(imag(EB)/real(EB));//degree//Load Angle
```

```
25  emf_B=abs(EB);//kV per phase//Induced emf of machine
        A
26  IA=abs(IA);//A
27  disp(IA,"Current on machine A(A) : ");
28  pfA=cos_thetaA;//power factor
29  disp(pfA,"Lagging power factor of machine A");
30  format('v',5);
31  disp(emf_A,"Induced emf of machine A(kV per phase)")
        ;
32  disp(del_A,"Load angle of machine A(degree)");
33  disp(del_B,"Load angle of machine B(degree)");
34  disp(emf_B,"Induced emf of machine B(kV per phase)")
        ;
35  //Answer in the textbook is not accurate.
```

Scilab code Exa 4.3 Synchronising power

```
1   //Exa 4.3
2   clc;clear;close;
3   format('v',5);
4   P=5;//MVA
5   V=1000;//V
6   speed=1500;//rpm//speed
7   ns=speed/60;//rps
8   f=50;//Hz
9   pf=0.8;//Power factor Lagging
10  Xs=20;//%//synchronous reluctance
11  Xs=Xs/100;///p.u.
12  disp("Part(a)");
13  V=1;//p.u.//on no load
14  E=1;//p.u.//on no load
15  Ps=V*E/Xs;//p.u.
16  Ps=Ps*P;//MW per elect. radian
17  Ps=Ps*1000;//kW per elect. radian
18  //1 mech. radian=%pi/90 elect. radian
```

```
19  Ps=Ps*%pi/90; //kW per mech. degree
20  disp(Ps,"Synchronising power per mech. degree(kW)");
21  d=0.5; //degree////displacement
22  Ts=Ps*1000*d/2/%pi/ns; //N-m
23  format('v',6);
24  disp(Ts,"Synchronising torque(N-m)");
25  disp("Part(b)");
26  theta=acosd(pf); //degree
27  E=V+(cosd(theta)-%i*sind(theta))*%i*Xs; //p.u.
28  Ps=V*E/Xs; //p.u.
29  Ps=Ps*P; //MW per elect. radian
30  Ps=Ps*1000; //kW per elect. radian
31  //1 mech. radian=%pi/90 elect. radian
32  Ps=Ps*%pi/90; //kW per mech. degree
33  Ps=abs(Ps); //kW per mech. degree
34  disp(Ps,"Synchronising power per mech. degree(kW)");
35  d=0.5; //degree////displacement
36  Ts=abs(Ps)*1000*d/2/%pi/ns; //N-m
37  disp(Ts,"Synchronising torque(N-m)");
38  //Answer in the textbook is not accurate.
```

Scilab code Exa 4.4 Synchronising power and torque

```
1   //Exa 4.4
2   clc;clear;close;
3   format('v',6);
4   P=2; //MVA
5   V=6000; //V
6   speed=750; //rpm//speed
7   ns=speed/60; //rps
8   Zs=6; //ohm/phase
9   f=50; //Hz
10  pf=0.8; //Power factor Lagging
11  //Calculation
12  I=P*10^6/sqrt(3)/V; //A//Current
```

```
13  theta = acosd ( pf ) ; // degree
14  E=V/ sqrt (3) +I *( cosd ( theta ) -%i* sind ( theta ) )*%i*Zs ; // V
15  Ps=V* sqrt (3)*E/Zs /1000; // kw per elect . radian
16  Ps=Ps *4*%pi /180; // kW per mech . degree
17  Ps= abs ( Ps ) ; // kW per mech . degree
18  disp ( Ps ,"Synchronising power per mech . degree (kW) " ) ;
19  Ts= abs ( Ps ) *1000/2/%pi/ ns ; // N–m
20  disp ( Ts ,"Synchronising torque (N–m) " ) ;
21  // Answer in the textbook is not accurate .
```

Scilab code Exa 4.5 Load current and power factor

```
1  // Exa 4.5
2  clc ; clear ; close ;
3  format ( 'v' ,6) ;
4  I =100; // A /// Current
5  V =11; // kV
6  Xs =4; // ohm / phase
7  f =50; // Hz
8  pf =0.8; // Power factor Lagging
9  // Calculation
10  theta = acosd ( pf ) ; // degree
11  disp ( " Part ( a ) " ) ;
12  E=V *1000/ sqrt (3) +I *( cosd ( theta ) -%i* sind ( theta ) )*%i*
       Xs ; // V
13  del = atand ( imag (E) / real (E) ) ; // degree
14  E= abs (E) ; // V / phase
15  disp (E ," Open circuit phase emf (V/ phase ) " ) ;
16  disp ( del ," Angle delta ( degree ) " ) ;
17  disp ( " Part ( b ) " ) ;
18  del_dash =10+ del ; // degree
19  P_by_V =E* sind ( del_dash ) /Xs ; // per phase
20  // P=V*I* cos_fi
21  I_cos_fi =P_by_V ;
22  // V *1000/ sqrt (3) +I *( cos_fi −%i* sin_fi )*%i*Xs=E
```

```
23  I_sin_fi ={ sqrt (E^2 -(4* I_cos_fi ^2) ) -V *1000/ sqrt (3)
        }/4;
24  tan_fi = I_sin_fi / I_cos_fi ;
25  fi = atand ( tan_fi ) ; // degree
26  I= I_cos_fi / cosd ( fi ) ; // A
27  disp (I ," New  load  current (A)");
28  pf = cosd ( fi ) ; // lagging  power  factor
29  disp ( pf ," Its  power  factor ( lagging )");
30  disp (" Part ( c )");
31  pf1 =0.8; /// original  power  factor
32  Idash =I* pf / pf1 ; // Current
33  disp ( Idash ," New  value  of  load  current (A)");
34  // Answer  is  slightly  differ  because  of  accuracy  in
        calculations .
```

Scilab code Exa 4.6 `Inertia Constant`

```
1  // Exa  4.6
2  clc ; clear ; close ;
3  format ( 'v ' ,7) ;
4  G =200; // MVA
5  H =6; // MJ/MVA /// Inertia  Constant
6  V =11; // kV
7  f =50; // Hz
8  L1 =120; // MW
9  L2 =160; // MW
10
11  // Calculation
12  disp (" Part ( a )");
13  Es =G*H; // MJ //// Stored  Energy
14  disp ( Es ," Stored  energy (MJ)");
15  disp (" Part ( b )");
16  Pa =L1 -L2 ; // MW
17  M =G*H /180/ f; // MJ−sec / elect . deg .
18  alfa = -Pa /M; // elect . deg ./ sec ^2 /// Retardation
```

```
19  disp(alfa,"Motor  retardation(elect.deg.sec^2)");
20  disp("Part(c)");
21  n=5;//cycles
22  t=n/f;//sec
23  del_change=1/2*-alfa*t^2;//elect.deg.
24  disp(del_change,"Change in power angle(elect.deg.)")
       ;
25  alfa=alfa*60/(180*4);//rpm/sec
26  ns=1500;//rpm
27  nr=ns+(-alfa)*t;//rpm;///rotor  speed
28  disp(nr,"Rotor speed at the end of 5 cycle(rpm)");
29  disp("Part(d)")
30  H2=4;//MJ/MVA
31  G2=150;//MVA
32  Gb=100;//MVA
33  Heb=H*G/Gb+H2*G2/Gb;//MJ/MVA
34  disp(Heb,"Inertia constant for the equivalent
       generator(MJ/MVA)");
```

Chapter 5

Frequency Control

Scilab code Exa 5.1 Change in power output

```
1  //Example 5.1
2  clc;clear;close;
3  P=100;//MW
4  drop=4;//%(No load to full load drop)
5  f=50;//Hz
6  disp("Part(i)");
7  p=1;//MW(For calculating per unit MW)
8  R=(drop/100)*f/p;//Hz/p.u.MW
9  disp(R,"Speed regulation in Hz/p.u.MW");
10 R=(drop/100)*f/P;//Hz/MW
11 disp(R,"Speed regulation in Hz/MW");
12 disp("Part(ii)");
13 del_f=-0.1;//Hz(Frequency drop)
14 delP=-1/R*del_f;//MW(Change in power output)
15 disp(delP,"Change in power output(MW)");
```

Scilab code Exa 5.2 Frequency Deviation

```
1  //Example 5.2
2  clc;clear;close;
3  format('v',6);
4  P=100;//MVA
5  f=50;//Hz
6  H=5;//kW-sec/kVA(Constant)
7  delP=50;//MW(Increased Load)
8  td=0.5;//s(Time delay)
9  P=P/1000;//kVA
10 KE=P*H;//kW-sec
11 delP=delP/1000;//kW(Increased Load)
12 KE_loss=delP*td;//kW-s
13 f_new=sqrt((KE-KE_loss)/KE)*f;//Hz
14 f_dev=(f-f_new)/f*100;//%(Frequency deviation)
15 disp(f_dev,"Frequency deviation(%)");
```

Scilab code Exa 5.3 Value of R

```
1  //Example 5.3
2  clc;clear;close;
3  format('v',7);
4  P1=500;//MW
5  P2=200;//MW
6  f=50;//Hz
7  delP=140;//MW(System load increase)
8  f_new=49.5;//Hz(Frequency after drop)
9  delP1=delP*P1/(P1+P2);//MW
10 delP2=delP*P2/(P1+P2);//MW
11 f_dev=f_new-f;//Hz
12 //For delPdash=0, R1 &R2 can be calculated as :
13 R1=-1/delP1*f_dev;//Hz/MW
14 R2=-1/delP2*f_dev;//Hz/MW
15 disp(R2,R1,"Value of R for unit 1 & 2(Hz/MW)");
```

Scilab code Exa 5.4 Static Frequency Drop

```
1  //Example 5.4
2  clc;clear;close;
3  format('v',8);
4  f=50;//Hz
5  R=2;//Hz/pu MW
6  Pr=10000;//MW(Rated Capacity)
7  P=Pr/2;//MW(Operating Power)
8  delP=2;//%(Load Increase)
9  del_f=f*1/100;//Hz(1% change in frequency)
10 del_PL=P*1/100;//MW(1% change in load)
11 //Rate of change of load with frequency :
12 D=del_PL/del_f;//MW/Hz
13 D=D/Pr;//p.u. MW/Hz
14 //Frequency response characteristic :
15 Beta=D+1/R;//p.u. MW/Hz
16 M=delP/100*P;//MW
17 M=M/Pr;//p.u. MW
18 del_fo=-M/Beta;//Hz
19 disp(del_fo,"Static frequency drop(Hz)")
20 R=%inf;
21 Beta=D+1/R;//p.u. MW/Hz
22 del_fo=-M/Beta;//Hz
23 disp(del_fo,"If speed governer loop is open,
       frequency drop(Hz)")
```

Scilab code Exa 5.5 Primary ALFC looop parameter

```
1  //Example 5.5
2  clc;clear;close;
3  format('v',7);
```

```
4  C=10000;//MW(Control area capacity)
5  P=5000;//MW
6  H=5;//s
7  R=3;//Hz/pu MW
8  f=50;//Hz
9  del_f=f*1/100;//Hz
10 del_PL=P*1/100;//MW
11 D=del_PL/del_f;//MW/Hz
12 D=D/C;//p.u. MW/Hz
13 //Primary ALFC loop parameters :
14 Kp=1/D;//Hz/p.u. MW
15 Tp=2*H/f/D;//s
16 disp("Primary ALFC loop parameters :")
17 disp(Kp,"Kp(Hz/p.u. MW)");
18 disp(Tp,"Tp(seconds)");
```

Scilab code Exa 5.6 `Increased Generation`

```
1  //Example 5.6
2  clc;clear;close;
3  format('v',6);
4  f=50;//Hz
5  R=2;//Hz/pu MW
6  Pr=10000;//MW(Rated Capacity)
7  P=Pr/2;//MW(Operating Power)
8  delP=2;//%(Load Increase)
9  del_f=f*1/100;//Hz(1% change in frequency)
10 del_PL=P*1/100;//MW(1% change in load)
11 //Rate of change of load with frequency :
12 D=del_PL/del_f;//MW/Hz
13 D=D/Pr;//p.u. MW/Hz
14 //Frequency response characteristic :
15 Beta=D+1/R;//p.u. MW/Hz
16 M=delP/100*P;//MW
17 M=M/Pr;//p.u. MW
```

```
18  del_fo=-M/Beta;//Hz
19  disp("Frequency  drop  contribution  to  increase  in
        load(MW)  :  ");
20  delP_fo=-del_fo*(D*Pr);//MW
21  disp(delP_fo);
22  disp("Increase  in  generation  to  meet  the  increase
        load(MW)  ");
23  delP_gen=-del_fo/R*Pr;//MW
24  disp(delP_gen);
```

Scilab code Exa 5.7 Frequency Deviation

```
1  //Example  5.7
2  clc;clear;close;
3  format('v',5);
4  G=100;//MVA
5  f=50;//Hz
6  n=3000;//rpm
7  L=25;//MW//Load
8  td=0.5;//sec
9  H=4.5;//MW-sec/MVA
10  //Calculation
11  KE=H*G;//MW-sec////at  no  load
12  KE_Loss=L*td;//MW-sec///due  to  increase  in  load
13  f_new=sqrt((KE-KE_Loss)/KE)*f;//Hz
14  delF=(f-f_new)/f*100;//%////frequency  deviation
15  disp(delF,"Frequency  deviation(%)");
```

Scilab code Exa 5.8 Change in step and frequency

```
1  //Example  5.8
2  clc;clear;close;
3  format('v',6);
```

```
 4  C =4000;//MW
 5  f =50;//Hz
 6  L =2500;//MW//Load
 7  R =2;//Hz/p.u.MW////Speed regulation constant
 8  H =5;//sec////Inertia constant
 9  delPL =2;//%////change in load
10  delf =1;//%////change in frequency
11  disp ("Part(a)");
12  D = delPL / delf * L / f;//MW/Hz
13  D = D / C;//p.u.MW/Hz
14  Beta = D +1/ R;//p.u.MW/Hz
15  delf0 = -0.2;//Hz
16  M = -( delf0 )* Beta;//p.u.MW
17  M = M * C;//MW
18  disp (M,"Largest change in step load(MW)");
19  disp ("Part(b)");
20  Kp =1/ D;//Hz/p.u.MW
21  Tp =2* H / f / D;//sec
22  Tdash =( R + Kp )/ R / Tp;//sec
23  disp (Tdash ,"(R+Kp)/(R*Tp) in seconds = ");
24  printf ('Change in frequency as a funtion of time, \
        ndelf(t) = -0.2*(1-epsilon^(-%f*t))',Tdash);
```

Scilab code Exa 5.9 Frequency response and value of Ki

```
 1  //Example 5.9
 2  clc;clear;close;
 3  format ('v',7);
 4  C =4000;//MW
 5  f =50;//Hz
 6  L = C;//MW//Load
 7  R =2.5;//%////Speed regulation constant
 8  H =5;//sec////Inertia constant
 9  delPL =1;//%////change in load
10  delf =1;//%////change in frequency
```

```
11  disp("Part(a)");
12  Ls=80;//MW;//increase in step to load
13  R=R/100*f;//z/p.u.MW
14  D=delPL/delf*L/f;//MW/Hz
15  D=D/C;//p.u.MW/Hz
16  M=Ls/L;//unitless//for given step load
17  Kp=1/D;//Hz/p.u.MW
18  Tp=2*H/f/D;//sec
19  Tdash1=(R+Kp)/R/Tp;//sec
20  disp(Tdash1,"(R+Kp)/(R*Tp) in seconds = ");
21  Tdash2=(R*Kp*M)/(R+Kp);//sec
22  disp(Tdash2,"(R*Kp*M)/(R+Kp) in seconds = ");
23  delf0=-Tdash2;//Hz////Static frequency error
24  disp(delf0,"Static frequency error(Hz)");
25  disp("Part(b)");
26  Ki=(1+Kp/R)^2/4/Tp/Kp;//p.u.MW/Hz
27  disp(Ki,"Critical value of Ki(p.u.MW/Hz)");
```

Scilab code Exa 5.10 Change in step and frequency error

```
 1  //Example 5.10
 2  clc;clear;close;
 3  format('v',7);
 4  s=poly(0,'s');//for transfer function
 5  Tg=0.2;//sec///time constant of governing system
 6  Tt=2;//sec///time constant of turbine
 7  Gr=1/(1+Tg*s);//Transfer function of governer
 8  Gt=1/(1+Tt*s);//Transfer function of turbine
 9  C=1500;//MW
10  f=50;//Hz
11  R=4;//%////Speed regulation constant
12  H=5;//sec////Inertia constant
13  delPL=1;//%////change in load
14  delf=1;//%////change in frequency
15  disp("Part(a)");
```

```
16  R=R/100*f;//z/p.u.MW
17  D=delPL/delf*C/f;//MW/Hz
18  D=D/C;//p.u.MW/Hz
19  Kp=1/D;//Hz/p.u.MW
20  Tp=2*H/f/D;//sec
21  Gp=Kp/(1+Tp*s);//Transfer function of power system
22  delFs=-Gp/(1+Gr*Gt*Gp/R);
23  disp(delFs,"delFs = M/s*");
24  disp("Part(b)");
25  delf0_by_M=-Kp/(1+Kp/R);//Hz
26  delf0=delf/100*f;//Hz
27  M=delf0/delf0_by_M;//p.u.MW
28  M=M*C;//MW
29  disp(M,"Largest step change(MW)");
30  //Transfer functions multiplication Gr*Gt*Gp is
        calculated & it is not possible to show together
        without calculated as in the book.
```

Scilab code Exa 5.11 Static Frequency Drop

```
1  //Example 5.11
2  clc;clear;close;
3  format('v',8);
4  GA=5000;//MW
5  GB=10000;//MW
6  R=2;//Hz/p.u.MW////Speed regulation constant
7  D=0.01;//p.u.MW/Hz
8  Ls=100;//MW//Load increase
9  RA=R*GB/GA;//Hz/p.u.MW
10 DA=D*GA/GB;//p.u.MW/Hz
11 RB=R;//Hz/p.u.MW
12 DB=D;//p.u.MW/Hz
13 Beta_A=DA+1/RA;//p.u.MW/Hz
14 Beta_B=DB+1/RB;//p.u.MW/Hz
15 MA=0;//Load increase
```

```
16  MB=Ls/GB;//p.u.MW
17  delf0=-MB/(Beta_A+Beta_B);//Hz
18  disp(delf0,"Static frequency drop(Hz)");
19  format('v',6);
20  delPAB=Beta_A*MB/(Beta_A+Beta_B);//p.u.MW
21  delPAB=delPAB*GB;//MW
22  disp(delPAB,"Change in tie line power(MW)");
```

Scilab code Exa 5.12 Change in frequency and tie line power

```
1   //Example 5.12
2   clc;clear;close;
3   format('v',8);
4   GA=500;//MW
5   GB=2000;//MW
6   RA=2.5;//Hz/p.u.MW////Speed regulation constant
7   RB=2;//Hz/p.u.MW////Speed regulation constant
8   Ls=20;//MW//Load increase
9   f=50;//Hz
10  delL=1;//%////change in load
11  delf=1;//%////change in frequency
12  DA=delL/delf*GA/f;//MW/Hz
13  DA=DA/GB;//p.u.MW/Hz
14  DB=delL/delf*GB/f;//MW/Hz
15  DB=DB/GB;//p.u.MW/Hz
16  RA=RA*GB/GA;//Hz/p.u.MW
17  Beta_A=DA+1/RA;//p.u.MW/Hz
18  Beta_B=DB+1/RB;//p.u.MW/Hz
19  disp("Part(a)");
20  MA=Ls/GB;//unitless
21  MB=0;//unitless
22  delf0=-MA/(Beta_A+Beta_B);//Hz
23  disp(delf0,"Change in frequency(Hz)");
24  delPAB=-Beta_B*MA/(Beta_B+Beta_A);//p.u.MW
25  delPAB=delPAB*GB;//MW
```

```
26 disp(delPAB,"Change in tie line power(MW)");
27 disp("Part(b)");
28 MB=Ls/GB;//unitless
29 MA=0;//unitless
30 delf0=-MB/(Beta_A+Beta_B);//Hz
31 disp(delf0,"Change in frequency(Hz)");
32 delPAB=Beta_A*MB/(Beta_B+Beta_A);//p.u.MW
33 delPAB=delPAB*GB;//MW
34 disp(delPAB,"Change in tie line power(MW)");
```

Scilab code Exa 5.13 Frequency of collision

```
1 //Example 5.13
2 clc;clear;close;
3 format('v',5);
4 G=4000;//MW
5 R=2;//Hz/p.u.MW////Speed regulation constant
6 H=5;//sec
7 C=600;//MW//Capacity
8 theta=40;//degree///Power angle
9 f=50;//Hz
10 disp("Part(a)");
11 T=C/G*cosd(theta);//sec
12 omega0=sqrt([2*%pi*f*T/H-(f/4/R/H)^2]);//radian/sec
13 disp(omega0,"Frequency of oscillation(radian/sec)");
14 disp("Part(b)");
15 delLB=100;//MW//change in load in area B
16 delPAB=delLB/2;//MW//because Beta_A=Beta_B
17 disp(delPAB,"Change in tie line power(MW)");
18 disp("Part(c)");
19 format('v',6);
20 omega0=sqrt([2*%pi*f*T/H]);//radian/sec
21 disp(omega0,"Frequency of oscillation(radian/sec)");
```

Scilab code Exa 5.14 Frequency at shared load

```
1  //Example 5.14
2  clc;clear;close;
3  format('v',6);
4  C1=300;//MW
5  C2=400;//MW
6  G1=4;//%//droop characteristics of governer
7  G2=5;//%//droop characteristics of governer
8  L=600;//MW
9  f=50;//Hz
10 //Load on first generator =L1
11 //Load on second generator =L-L1
12 //f-G1*f/100*(L1/C1)=f-G2*f/100*(L2/C2)
13 L1=G2*L/C2/(G1/C1+G2/C2);//MW
14 L2=L-L1;//MW
15 disp(L1,"Load on first generator(MW)");
16 disp(L2,"Load on second generator(MW)");
17 fLoad=f*(1-L1/C1*G1/100);//Hz
18 disp(fLoad,"Frequency at load(Hz)");
```

Scilab code Exa 5.15 Change in frequency

```
1  //Example 5.15
2  clc;clear;close;
3  format('v',6);
4  G=100;//MVA
5  f=50;//Hz
6  delL=50;//MW
7  Tc=0.4;//sec
8  H=5;///kWs/kVA
9  KE=G*1000*H;//kWs
```

65

```
10  delKE=delL*1000*Tc;////kWs///due to decrease in load
11  fnew=sqrt((KE+delKE)/KE) *f;//Hz
12  fdev=(fnew-f)/f*100;//%
13  disp(fnew,"New frequency(Hz)");
14  disp(fdev,"Frequency deviation(%)");
```

Scilab code Exa 5.16 `Percentage frequency deviation`

```
1  //Example 5.16
2  clc;clear;close;
3  format('v',7);
4  G=100;//MVA
5  f=50;//Hz
6  delL=60;//MW
7  Tc=0.35;//sec
8  H=5;///kWs/kVA
9  KE=G*1000*H;//kWs
10 delKE=(G-delL)*1000*Tc;////kWs///due to decrease in
       load
11 fnew=sqrt((KE+delKE)/KE) *f;//Hz
12 fdev=(fnew-f)/f*100;//%
13 disp(fnew,"New frequency(Hz)");
14 format('v',6);
15 disp(fdev,"Frequency deviation(%)");
```

Scilab code Exa 5.17 `Rate of frequency increase`

```
1  //Example 5.17
2  clc;clear;close;
3  format('v',6);
4  KE=1500;//MJ
5  Pin=5;//MW
6  f=50;//Hz
```

```
7  t=1;//sec
8  delKE=Pin*t;////MJ///due to power inputs
9  fnew=sqrt((KE+delKE)/KE) *f;//Hz
10 delf=fnew-f;///Hz/second
11 disp(delf,"Frequency increase rate(Hz/sec)");
```

Scilab code Exa 5.18 `Primary ALFC looop parameter`

```
1  //Example 5.18
2  clc;clear;close;
3  format('v',6);
4  C=2000;//MW///Capacity
5  L=1000;//MW//Load
6  H=5;//kWs/KVA
7  R=2.4;//Hz/puMW//Regulation
8  f=50;//Hz
9  delL=1;//%////change in load
10 delf=1;//%////change in frequency
11 D=delL/delf*L/f;//MW/Hz
12 D=D/C;//p.u.MW/Hz
13 Kp=1/D;//Hz/p.u.MW
14 Tp=2*H/f/D;//sec
15 disp("Primary ALFC loop parameters are : ");
16 disp(D,"D(p.u.MW/Hz)");
17 disp(Kp,"Kp(Hz/p.u.MW)");
18 disp(Tp,"Tp(sec)");
```

Scilab code Exa 5.19 `Compute the time error`

```
1  //Example 5.19
2  clc;clear;close;
3  format('v',6);
4  Tp=10;//sec
```

```
 5  Tg=0;//sec
 6  Tt=0;//sec
 7  Kp=100;//Hz/p.u.MW
 8  R=3;///Hz/CuMW
 9  delPD=0.1;//p.u.
10  Ki=0.1;//constant
11  f=50;//Hz
12  s=poly(0,'s');
13  delFs=-Kp/Tp*[delPD/(s^2+s*{(1+Kp/R)/Tp})+Ki*Kp/Tp];
14  n=1;//cycle
15  time_error=n/f;//sec
16  disp(time_error,"Total time error(sec)");
```

Scilab code Exa 5.20 Generated output Power and frequency

```
 1  //Example 5.20
 2  clc;clear;close;
 3  format('v',6);
 4  L=14;//MW//Total Load
 5  C1=15;//MW
 6  R1=3;//%//speed regulation
 7  C2=4;//MW
 8  R2=4;//%//speed regulation
 9  LB=4;//MW//Load on bus bar
10  LA=10;//MW///Load on bus bar
11  f=50;//Hz
12  //Load on station A= L1 MW
13  //Load on station B= L-L1 MW
14  //f-C1*f/100*(L1/C1)=f-C2*f/100*(L2/C2)
15  L1=R2*L/C2/(R1/C1+R2/C2);//MW
16  L2=L-L1;//MW
17  disp(L1,"Load generation at station A(MW)");
18  disp(L2,"Load generation at station B(MW)");
19  Pt=L1-LA;//MW//Power transmitted A to B
20  f_oper=f-R1/100/C1*(L1)*f;//Hz
```

```
21 disp(f_oper,"Operating Frequency(Hz)");
```

Scilab code Exa 5.21 `No Load Frequencies`

```
1  //Example 5.21
2  clc;clear;close;
3  format('v',6);
4  C1=300;//MW
5  C2=400;//MW
6  G1=4;//%//droop characteristics of governer
7  G2=6;//%//droop characteristics of governer
8  L=400;//MW
9  f=50;//Hz
10 L1=C1*L/(C1+C2);//MW//Load on 300 MW generator
11 L2=L*C2/(C1+C2);//MW//Load on 400 MW generator
12 f01=f*(C1)/(C1-G1/100*L1);//Hz///No load frequency
13 disp(f01,"No load frequency of 300 MW generator(Hz)"
      );
14 f02=f*(C2)/(C2-G2/100*L2);//Hz///No load frequency
15 disp(f02,"No load frequency of 400 MW generator(Hz)"
      );
```

Scilab code Exa 5.22 `Generation and transfer of power`

```
1  //Example 5.22
2  clc;clear;close;
3  format('v',6);
4  C1=200;//MW
5  C2=100;//MW
6  R1=1.5;//%//speed regulation
7  R2=3;//%//speed regulation
8  L=100;//MW///Load on each bus
9  f=50;//Hz
```

```
10  RA=R1/100*f/C1;//Hz/MW
11  RB=R2/100*f/C2;//Hz/MW
12  //Let PA= generation at plant A
13  //PB=2*L-PA will be generation at plant B
14  //RA*PA=RB*PB
15  PA=RB*2*L/(RA+RB);//MW
16  PB=2*L-PA;//MW
17  disp(PA,"Load generation at plant A(MW)");
18  disp(PB,"Load generation at plant B(MW)");
19  Pt=PA-L;//MW///Power transfer
20  disp(Pt,"Power transfer from A to B(MW)");
```

Scilab code Exa 5.23 `Voltage Boost Needed`

```
1  //Example 5.23
2  clc;clear;close;
3  format('v',7);
4  Z=1.5+%i*2.5;//ohm
5  V=11;//kV
6  P=20;//MW
7  pf=0.8;//power factor
8  theta=acosd(pf);
9  I=P*1000/sqrt(3)/V/pf;//
10 I=I*expm(%i*-theta*%pi/180);//A
11 Vdrop=I*Z;//V
12 Vboost=Vdrop;//V
13 disp(Vboost,"Voltage boost needed at station A(V)");
```

Scilab code Exa 5.24 `Phase angle and pu real and active`

```
1  //Example 5.24
2  clc;clear;close;
3  format('v',6);
```

```
 4  Z=3+%i*9;//%///impedence
 5  Z=Z/100;//p.u.///Impedence
 6  I=1;//p.u.
 7  IZ=Z;//p.u.
 8  disp("Part(a)");
 9  //2*I^2-2*cos(del)=[abs(IZ)]^2
10  cos_del=acosd((2*I^2-[abs(IZ)]^2)/2);//degree
11  disp(cos_del,"Phase angle between two station(degree
       )");
12  angle_abc=87.277;///degree
13  theta=180-angle_abc-atand(imag(IZ)/real(IZ));//
       degree
14  Preal=I^2*cosd(theta);//p.u.
15  disp(Preal,"Real power transfer(p.u.)");
16  Preactive=I^2*sind(theta);//p.u.
17  disp(Preactive,"Reactive power transfer(p.u.)");
18  disp("Part(b)");
19  //1.05^2+1^2-2*1.05*cos(del)=[abs(IZ)]^2
20  cos_del=acosd((1.05^2+1^2-[abs(IZ)]^2)/2/1.05);//
       degree
21  disp(cos_del,"Phase angle between two station(degree
       )");
22  angle_dbc=60.53;///degree
23  theta=atand(imag(IZ)/real(IZ))-angle_dbc//degree
24  Preal=I^2*cosd(theta);//p.u.
25  disp(Preal,"Real power transfer(p.u.)");
26  Preactive=I^2*sind(theta);//p.u.
27  disp(Preactive,"Reactive power transfer(p.u.)");
28  //Answer in the textbook is not accurate.
```

Chapter 6

Reactive power control

Scilab code Exa 6.1 Voltage and power factor

```
1  //exa 6.1
2  clc;clear;close;
3  format('v',6);
4  kV=220;//kV
5  Z=0.8+%i*0.2;//pu
6  V=1;//V(Voltage at load terminal)
7  X=0.2+0.05;//pu(line and transformer reactance)
8  P=real(Z);//pu
9  Q=imag(Z);//pu
10 BaseMVA=100;//MVA
11 BasekV=220;//kV
12 I=sqrt((P^2+Q^2)/V^2)*expm(%i*atan(-imag(Z),real(Z))
      );//pu
13 Vb=V+I*(X*expm(%i*%pi/2));//pu(Voltage at 200 kV bus
      )
14 fi_p=atand(imag(Vb),real(Vb));//degree(power angle)
15 Vb=abs(Vb)*kV;//kV(Voltage at 200 kV bus)
16 pf=cosd(fi_p+atand(imag(Z),real(Z)));//power factor
      at 220 kV bus
17 disp(Vb,"Voltage at 220 kV bus (kV)");
18 disp(pf,"Power factor at 220 kV bus (lagging)");
```

Scilab code Exa 6.2 Voltage and power factor

```
1 //exa 6.2
2 clc;clear;close;
3 format('v',6);
4 kV=220;//kV
5 Z=0.8+%i*0.2;//pu
6 V=1;//V(Voltage at load terminal)
7 X=0.2+0.05;//pu(line and transformer reactance)
8 P=real(Z);//pu
9 Q=imag(Z);//pu
10 BaseMVA=100;//MVA
11 BasekV=220;//kV
12 I=sqrt((P^2+Q^2)/V^2);//pu
13 Vb=V+I*(X*expm(%i*%pi/2));//pu(Voltage at 200 kV bus
      )
14 fi_p=atand(imag(Vb),real(Vb));//degree(power angle)
15 Vb=abs(Vb)*kV;//kV(Voltage at 200 kV bus)
16 pf=cosd(fi_p);//power factor at 220 kV bus
17 disp(Vb,"Voltage at 220 kV bus (kV)");
18 format('v',5);
19 disp(pf,"Power factor at 220 kV bus (lagging)");
```

Scilab code Exa 6.3 Find ABCD Parameters

```
1 //exa 6.3
2 clc;clear;close;
3 format('v',7);
4 l=350;//km(length of line)
5 Z=180*expm(%i*75*%pi/180);//ohm/phase(Total)
6 Y=1*10^-3*expm(%i*90*%pi/180);//Siemens/phase(Total)
```

73

```
7   z=Z/l;//ohm/km
8   y=Y/l;//Siemens/km
9   re=l*sqrt(z*y);//
10  Zc=sqrt(z/y);//ohm
11  disp("Part(a) A,B,C,D parameters are : ");
12  A=cosh(re);//unitless
13  D=A;//unitless
14  B=Zc*sinh(re);//ohm
15  C=sinh(re)/Zc;//unitless
16  A_mag=abs(A);//unitless
17  A_angle=atand(imag(A)/real(A));//degree
18  B_mag=abs(B);//ohm
19  B_angle=atand(imag(B)/real(B));//degree
20  C_mag=abs(C);//unitless
21  C_angle=atand(imag(C)/real(C));//degree
22  C_angle=C_angle+180;//degree(Converting -ve to +ve
        angle)
23  D_mag=abs(D);//unitless
24  D_angle=atand(imag(D)/real(D));//degree
25  disp(A_mag,"Magnitude of A : ");
26  format('v',5);
27  disp(A_angle,"Angle of A(degree) : ");
28  format('v',7);
29  disp(B_mag,"Magnitude of B(ohm) : ");
30  format('v',6);
31  disp(B_angle,"Angle of B(degree) : ");
32  format('v',8);
33  disp(C_mag,"Magnitude of C : ");
34  format('v',6);
35  disp(C_angle,"Angle of C(degree) : ");
36  format('v',7);
37  disp(D_mag,"Magnitude of D : ");
38  format('v',5);
39  disp(D_angle,"Angle of D(degree) : ");
40  //60% series compensation
41  B=B-%i*60/100*abs(Z)*sind(atand(imag(Z),real(Z)));//
        ohm(considering series compensation=60%)
42  //For Equivalent pi-circuit
```

```
43  disp("Part(b) A,B,C,D parameters of compensated line
        are : ");
44  Ydash=2/Zc*[(cosh(re)-1)/sinh(re)];//S
45  A=1+B*Ydash/2;//unitless
46  D=A;//unitless
47  C=2*Ydash/2+B*(Ydash/2)^2;//unitless
48  A_mag=abs(A);//unitless
49  A_angle=atand(imag(A)/real(A));//degree
50  B_mag=abs(B);//ohm
51  B_angle=atand(imag(B)/real(B));//degree
52  C_mag=abs(C);//unitless
53  C_angle=atand(imag(C)/real(C));//degree
54  C_angle=C_angle+180;//degree(Converting -ve to +ve
        angle)
55  D_mag=abs(D);//unitless
56  D_angle=atand(imag(D)/real(D));//degree
57  format('v',4);
58  disp(B_mag,"Magnitude of B(ohm) : ");
59  format('v',6);
60  disp(B_angle,"Angle of B(degree) : ");
61  format('v',7);
62  disp(A_mag,"Magnitude of A : ");
63  format('v',5);
64  disp(A_angle,"Angle of A(degree) : ");
65  format('v',6);
66  disp(C_mag,"Magnitude of C : ");
67  format('v',5);
68  disp(C_angle,"Angle of C(degree) : ");
69  format('v',7);
70  disp(D_mag,"Magnitude of D : ");
71  format('v',5);
72  disp(D_angle,"Angle of D(degree) : ");
73  //Answer for some parts are not accurate in the
        textbook.
```

Scilab code Exa 6.4 `Constant of nominal pi circuit`

```
1  //exa 6.4
2  clc;clear;close;
3  format('v',6);
4  l=350;//km(length of line)
5  Z=180*expm(%i*75*%pi/180);//ohm/phase(Total)
6  Y=1*10^-3*expm(%i*90*%pi/180);//Siemens/phase(Total)
7  z=Z/l;//ohm/km
8  y=Y/l;//Siemens/km
9  re=l*sqrt(z*y);//
10 Zc=sqrt(z/y);//ohm
11 disp("For Uncompensated Line, Constants are :");
12 B=Z;//ohm//B Parameter
13 A=1+Z*Y/2;//unitless//A Parameter
14 D=A;//unitless//D Parameter
15 C=Y*(1+Z*Y/4);//S//C Parameter
16 A_mag=abs(A);
17 A_angle=atand(imag(A)/real(A));//degree
18 B_mag=abs(B);
19 B_angle=atand(imag(B)/real(B));//degree
20 C_mag=abs(C);
21 C_angle=atand(imag(C)/real(C))+180;//degree
22 D_mag=abs(D);
23 D_angle=atand(imag(D)/real(D));//degree
24 disp(B_angle,B_mag,"Magnitude and Angle(degree) of B
      (ohm) is ");
25 disp(A_angle,A_mag,"Magnitude and Angle(degree) of A
        is ");
26 disp(D_angle,D_mag,"Magnitude and Angle(degree) of D
        is ");
27 format('v',9);
28 disp(C_mag,"Magnitude of C(S) is ");
29 format('v',6);
30 disp(C_angle,"Angle(degree) of C is ");
31 disp("For Compensated Line, Constants are :");
32 B=Z-0.6*%i*406;//ohm//B Parameter
33 A=1+conj(B)*Y/2;//unitless//A Parameter
```

```
34  D=A;//unitless//D Parameter
35  C=Y*(1+Z*Y/4);//S//C Parameter
36  A_mag=abs(A);
37  A_angle=atand(imag(A)/real(A));//degree
38  B_mag=abs(B);
39  B_angle=-atand(imag(B)/real(B));//degree
40  C_mag=abs(C);
41  C_angle=atand(imag(C)/real(C))+180;//degree
42  D_mag=abs(D);
43  D_angle=atand(imag(D)/real(D));//degree
44  disp(B_angle,B_mag,"Magnitude and Angle(degree) of B
        (ohm) is ");
45  disp(A_angle,A_mag,"Magnitude and Angle(degree) of A
        is ");
46  disp(D_angle,D_mag,"Magnitude and Angle(degree) of D
        is ");
47  format('v',9);
48  disp(C_mag,"Magnitude of C(S) is ");
49  format('v',6);
50  disp(C_angle,"Angle(degree) of C is ");
```

Scilab code Exa 6.5 `VAR injection ay bus`

```
1  //exa 6.5
2  clc;clear;close;
3  format('v',6);
4  kv1=220;//kv
5  kv2=132;//kv
6  baseMVA=200;//MVA
7  //Base impedence in 132 kv circuit
8  baseZ2=kv2^2/baseMVA;//ohm
9  z1=%i*75;//ohm
10  z2=%i*70;//ohm
11  z3=%i*90;//ohm
12  z1=z1/baseZ2;//pu
```

```
13  z2=z2/baseZ2;//pu
14  z3=z3/baseZ2;//pu
15  X_AD=%i*0.08+z1;//pu//Reactance from A to D
16  X_BD=%i*0.08+z2;//pu//Reactance from A to D
17  Zp=z3*X_AD*X_BD/(z3*X_AD+z3*X_BD+X_BD+X_AD);//
        parallel combination
18  sc_D=baseMVA/abs(Zp);//MVA//Short Circuit MVA at D
19  delQBYdelV=sc_D/kv2;//MVA/kv
20  delQ=delQBYdelV*4;//MVar
21  disp(delQ,"Var injection at Bus D(MVar) : ");
22  //Answer in the textbook is not accurate.
```

Scilab code Exa 6.6 Capacity of shunt compensation

```
1   //exa 6.6
2   clc;clear;close;
3   format('v',6);
4   A=0.98*expm(%i*3*%pi/180);//Constant
5   B=110*expm(%i*75*%pi/180);//ohm/phase
6   P=50;//MVA
7   pf=0.8;//lagging
8   V=132;//kV
9   //Formula : Pr=|Vs|*|Vr|/|B|*cosd(Beta-delta)-|A|*|
        Vr|^2/|B|*cosd(Beta-alfa) :
10  betaSUBdelta=acosd((P*pf+abs(A)*V^2/abs(B)*cosd(
        atand(imag(B),real(B))-atand(imag(A),real(A))))/V
        ^2*abs(B));
11  Qr=V^2/abs(B)*sind(betaSUBdelta)-abs(A)*V^2/abs(B)*
        sind(atand(imag(B),real(B))-atand(imag(A),real(A)
        ));//MVar
12  Qr=P*0.6-Qr;//MVar//Since load require lagging
        component
13  disp(Qr,"(a) Capacity of shunt compensation
        equipment(MVar) : ");
14  //part(b)
```

```
15  // Formula : Pr=|Vs|*|Vr|/|B|*cosd(Beta-delta)-|A|*|
       Vr|^2/|B|*cosd(Beta-alfa) :
16  format('v',5);
17  P=0; //MW
18  betaSUBdelta=acosd((P*pf+abs(A)*V^2/abs(B)*cosd(
       atand(imag(B),real(B))-atand(imag(A),real(A))))/V
       ^2*abs(B));
19  Qr=V^2/abs(B)*sind(betaSUBdelta)-abs(A)*V^2/abs(B)*
       sind(atand(imag(B),real(B))-atand(imag(A),real(A)
       )); //MVar
20  Qr=P*0.6-Qr; //MVar// Since load require lagging
       component
21  disp(-Qr,"(b) Capacity of shunt compensation
       equipment(MVar) : ");
```

Scilab code Exa 6.7 Find tap settings

```
 1  //exa 6.7
 2  clc;clear;close;
 3  format('v',6);
 4  V=220; //kV
 5  Z=20+%i*60; //ohm
 6  Pr=100; //MVA
 7  pf=0.8; //lagging pf
 8  P=Pr*10^6*pf/3; //W
 9  theta=acosd(pf); //degree
10  Q=Pr*10^6*sind(theta)/3; //Vars
11  V1=V/sqrt(3)*1000; //V
12  V2=V1; //V
13  //ts^2*[1-(R*P+X*Q)/V1/V2]=V2/V1
14  ts=sqrt(V2/V1/[1-(real(Z)*P+imag(Z)*Q)/V1/V2]);
15  tr=1/ts;
16  disp(ts,"Tap settings : ts is ");
17  format('v',5);
18  disp(tr,"tr is ");
```

Scilab code Exa 6.8 Find tap settings

```
1  //exa 6.8
2  clc;clear;close;
3  format('v',6);
4  kV1=132;//kV
5  kV2=33;//kV
6  kV3=11;//kV
7  MVA1=75;//MVA
8  MVA2=50;//MVA
9  MVA3=25;//MVA
10 X=0.12;//p.u.
11 //part(a)
12 P=60;//MW
13 V1=125;//kV
14 V1=V1/kV1;//p.u.
15 Q=MVA2/MVA1;//p.u.
16 //V1=Vn+X*Q/Vn
17 Vn=poly(0,'Vn');
18 eqn=Vn^2-V1*Vn+X*Q
19 Vn=roots(eqn);//p.u.
20 Vn=Vn(1);//p.u.
21 Vn=Vn*kV1;//kV
22 k=Vn/kV2;//Transformer ratio
23 disp(k,"Under Load condition, transformer ratio is "
       );
24 //part(b)
25 V1=140;//kV
26 V1=V1/kV1;//p.u.
27 Q=MVA3/MVA1;//p.u.
28 //V1=Vn+X*Q/Vn
29 Vn=poly(0,'Vn');
30 eqn=Vn^2-V1*Vn+X*Q
31 Vn=roots(eqn);//p.u.
```

```
32  Vn=Vn(1);//p.u.
33  Vn=Vn*kV1;//kV
34  k=Vn/kV2;//Transformer ratio
35  disp(k,"Under No Load condition, transformer ratio
        is ");
```

Scilab code Exa 6.9 Settings of tap changes

```
1  //exa 6.9
2  clc;clear;close;
3  format('v',7);
4  V=132;//kV
5  Z=25+%i*66;//ohm
6  Pr=100;//MW
7  pf=0.9;//lagging pf
8  P=Pr*10^6/3;//W
9  theta=acosd(pf);//degree
10 Q=Pr*10^6*tand(theta)/3;//vars
11 V1=V/sqrt(3)*1000;//V
12 V2=V1;//V
13 //ts^2*[1-(R*P+X*Q)/V1/V2]=V2/V1
14 ts=sqrt(V2/V1/[1-(real(Z)*P+imag(Z)*Q)/V1/V2]);
15 tr=1/ts;
16 disp(ts,"Tap settings : ts is ");
17 format('v',5);
18 disp(tr,"tr is ");
```