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

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

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

Scilab code Exa 1.2 Demand and Diversity Factor

```
//exa 1.2
clc;clear;close;
format('v',6);
LoadA=2.5*1000;//W
//12 midnight to 5am
d1A=100;//W
//5am to 6am
d2A=1.1*1000;//W
//6am to 8am
d3A=200;//W
//8am to 5pm
d4A=0;//W
//5pm to 12 midnight
d5A=500;//W
LoadB=3*1000;//W
//11 pm to 7am
d1B=0;//W
//7 am to 8 am
d2B=300;//W
//8 am to 10 am
d3B=1*1000;//W
//10 am to 6 pm
d4B=200;//W
```

```
//6 pm to 11 pm
d5B=600;//W
DEMAND_A=[d1A d2A d3A d4A d5A];//W
DEMAND_B=[d1B d2B d3B d4B d5B];//W
max_demand_A=max(DEMAND_A);//W
max_demand_B=max(DEMAND_B);//W
df_A=max_demand_A/LoadA;//demand factor
df_B=max_demand_B/LoadB;//demand factor
disp(df_B,df_A,"Demand factor of consumer A & B are"
    );
gd_factor=(max_demand_A+max_demand_B)/max_demand_A;
disp(gd_factor,"Group diversity factor")
E_A=d1A*5+d2A*1+d3A*2+d4A*9+d5A*7;//Wh
E_B=d1B*8+d2B*1+d3B*2+d4B*8+d5B*5;//Wh
E_A=E_A/1000;//kWh
E_B=E_B/1000;//kWh
disp(E_B,E_A,"Energy consumed by A & B during 24
    hours(kWh)")
Emax_A=max_demand_A*24/1000;//kWh
Emax_B=max_demand_B*24/1000;//kWh
 disp(Emax_B,Emax_A,"Maximum energy consumer A & B
     can consume during 24 hours(kWh)")
ratio_A=E_A/Emax_A;
format('v',7);
ratio_B=E_B/Emax_B;
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

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

```
n2=20;//No. of general purpose shops
L2=2;//kW//Each Shop Load
df=0.8;//demand factor
//1 Floor mill
L3=10;//kW//Load
df3=0.7;//demand factor
//1 Saw mill
L4=5;//kW//Load
df4=0.8;//demand factor
//1 Laundry
L5=20;//kW//Load
df5=0.65;//demand factor
//1 Cinema
L6=80;//kW//Load
df6=0.5;//demand factor
//Street lights
n7=200;//no. of tube lights
L7=40;//W//Load of each light
//Residential Load
df8=0.5;//demand factor
gdf_r=3;//group diversity factor
pdf_r=1.25;//peak diversity factor
//Commertial Load
gdf_c=2;//group diversity factor
pdf_c=1.6;//peak diversity factor
//Solution :
//Maximum demand of each apartment
dmax_1a=L1*df8;//kW
//Maximum demand of 600 apartment
dmax_a=n1*dmax_1a/gdf_r;//kW
//demand of apartments at system peak time
d_a_sp=dmax_a/pdf_r;//kW
//Maximum Commercial demand
dmax_c=(n2*L2*df+L3*df3+L4*df4+L5*df5+L6*df6)/gdf_c;
    //kW
//Commercial demand at system peak time
d_c_sp=dmax_c/pdf_c;//kW
//demand of street light at system peak time
```

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

Scilab code Exa 1.4 `Load Factor and Energy Supplied`

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

Scilab code Exa 1.5 `Capacity and utilisation factor`

```
//exa 1.5
clc;clear;close;
format('v',6);
C=125;//MW//Installed Capacity
//12 to 5 am
L1=20;//MW
t1=5;//hours
//5 to 9 am
L2=40;//MW
t2=4;//hours
//9 to 6 pm
L3=80;//MW
t3=9;//hours
//6 to 10 pm
L4=100;//MW
t4=4;//hours
//10 to 12 am
L5=20;//MW
t5=2;//hours
//Energy Poduced in 24 hours
E=L1*t1+L2*t2+L3*t3+L4*t4+L5*t5;//MWh
LF=E/24;//%//Load Factor
CF=LF/C;//%//Capacity Factor
disp(CF,"Capacity Factor(%) : ");
UF=100/C;//%//Utilisation Factor
disp(UF,"Utilisation Factor(%) : ");
```

Scilab code Exa 1.6 Energy Load curve and Mass Curve

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

```
//5 to 9 am
L2=40;//MW
E2=E1+(L2-L1)*17;//MWh
//9 to 6 pm
L3=80;//MW
E3=E2+(L3-L2)*13;//MWh
//6 to 10 pm
L4=100;//MW
E4=E3+(L4-L3)*4;//MWh
//Plotting Energy load curve
L=[0,L1,L2,L3,L4];//MW
E=[0,E1,E2,E3,E4];//Mwh
subplot(2,1,1)
plot(E,L)
xlabel('Energy(MWh)');
ylabel('Load(MW)');
title('Energy Load Curve');
//Energy Supplied
//Upto 5am
t1=5;//hours
E1=L1*t1;//MWh
//Upto 9am
t2=4;//hours
E2=E1+L2*t2;//MWh
//Upto 6pm
t3=9;//hours
E3=E2+L3*t3;//MWh
//Upto 10pm
t4=4;//hours
E4=E3+L4*t4;//MWh
//Upto 12pm
t4=2;//hours
E4=E3+L4*t4;//MWh
//Plotting Mass curve
T=[0,1,2,3,4];//MW
E=[0,E1,E2,E3,E4];//Mwh
subplot(2,1,2)
plot(T,E)
```

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

Scilab code Exa 1.7 Load Factor Plant capacity reserve capacity

```
//exa 1.7
clc;clear;close;
format('v',9);
dmax=40;//MW//Maximum demand
CF=0.5;//Capacity Factor
UF=0.8;//Utilisation Factor
LF=CF/UF;///Load Factor
disp(LF,"(a) Load Factor : ");
C=dmax/UF;//MW//Plant Capacity
disp(C,"(b) Plant Capacity(MW) : ");
RC=C-dmax;//MW//Reserve Capacity
disp(RC,"(c) Reserve Capacity(MW) : ");
p=dmax*LF*24*365;//MWh//Annual Energy Production
disp(p,"(d) Annual Energy Production(MWh) : ");
```

Scilab code Exa 1.8 Load Curve and energy required

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

```
L4=100;//MW//6pm
t4=2;//hours
L5=150;//MW//8pm
t5=2;//hours
L6=80;//MW//10pm
t6=2;//hours
L7=50;//MW
//Energy Required in 24 hours
E=L1*t1+(L2+L3)/2*t2+(L3+L4)/2*t3+(L4+L5)/2*t4+(L5+
   L6)/2*t5+(L6+L1)/2*t6;//MWh
disp(E,"Energy required in one day(MWh)");
DLF=E/L5/24*100;//%//Daily Load Factor
disp(DLF,"Daily Load Factor(%)");
//Plotting load curve
T=[0,1,2,3,4,5,6];//Slots
L=[L1,L2,L3,L4,L5,L6,L7];//MW
plot(T,L)
ylabel('Load(MW)');
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');
title('Chronological Load Curve');
```

Scilab code Exa 1.9 Load duration curve and Mass curve

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

```
L5=150;//MW//8pm
t5=2;//hours
L6=80;//MW//10pm
t6=2;//hours
L7=50;//MW
//Load Duration Curve
l1=L5;//Mw
l2=L4;//MW
l3=L1;//MW
L=[l1,l2,l2,l3,l3]
T=0:6:24;//Duration in hours
subplot(2,1,1)
plot(T,L)
ylabel('Load(MW)');
xlabel('Hours');
title('Load Duration Curve');
//Energy Consumed
//Upto 5am
t1=5;//hours
E1=L1*t1;//MWh
//Upto 9am
t2=4;//hours
E2=E1+L2*t2;//MWh
//Upto 6pm
t3=9;//hours
E3=E2+L3*t3;//MWh
//Upto 10pm
t4=4;//hours
E4=E3+L4*t4;//MWh
//Upto 12pm
t4=2;//hours
E4=E3+L4*t4;//MWh
//Plotting Mass curve
T=[0,1,2,3,4];//MW
E=[0,E1,E2,E3,E4];//Mwh
subplot(2,1,2)
plot(T,E)
ylabel('Energy(MWh)');
```

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

Scilab code Exa 1.10 Station Capacity and Reserve capacity

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

Scilab code Exa 1.11 Maximum demand and annual energy supplied

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

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

Scilab code Exa 1.12 `Weekly Load Factor`

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

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

Scilab code Exa 1.13 Annual Load factor

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

Scilab code Exa 1.14 Peak Load on transformer and feeder

```
//exa 1.14
clc;clear;close;
format('v',5);
//Transformer1
Lm=300;//kW
df_m=0.6;//demand factor
Lc=100;//kW//Commercial Load
df_c=0.5;//demand factor
//Transformer2
Lr2=500;//kW//Residential Load
df_Lr2=0.4;//demand factor
//Transformer3
```

```
Lr3=400;//kW
df_Lr3=0.5;//demand factor
//Diversity factors
df1=2.3;
df2=2.5;
df3=2;
DF=1.4;//Diversity factor between transformers
//Solution :
disp("Part(a)");
Lp1=(Lm*df_m+Lc*df_c)/df1;//kW//Peak load on Transformer1
disp(Lp1,"Peak load on Transformer1(kW)");
Lp2=Lr2*df_Lr2/df2;//kW//Peak load on Transformer2
disp(Lp2,"Peak load on Transformer2(kW)");
Lp3=Lr3*df_Lr3/df3;//kW//Peak load on Transformer3
disp(Lp3,"Peak load on Transformer3(kW)");
disp("Part(b)");
LpF=(Lp1+Lp2+Lp3)/DF;//Peak load on feeder
disp(LpF,"Peak load on feeder(kW)");
```

Scilab code Exa 1.16 Max Load and Load factor

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

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

Scilab code Exa 1.17 Real Power

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

Scilab code Exa 1.18 Total Energy generated

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

Scilab code Exa 1.19 Motor Load Change

```
//exa 1.19 page 25
clc;clear;close;
format('v',5);
V=400;//V
s1=0.03;//initial slip
delV=1;//%///Voltage Drop
R1=0.290;//ohm/phase
R2=0.15;//ohm/phase
X=0.7;//ohm/phase(X1+X2)
//V1^2*s1=V2^2*s2 for speed independent torque
//taking for calculating s2
V1=1;//V
V2=V1-V1*delV/100;//V
s2=V1^2/V2^2*s1;//slip
I2ByI1=sqrt([R1+R2/s1]^2+X^2)/sqrt([R1+R2/s2]^2+X^2)*(V2/V1)
delI=(I2ByI1-1)*100;//%//Current Increase
disp(delI,"1% drop in Voltage increases current by(%)");
//P=(R1+R2/s)*I^2
P2ByP1=(R1+R2/s2)/(R1+R2/s1)*I2ByI1^2;//ratio
delP=(1-P2ByP1)*100;//%//Power Decrease
format('v',4);
disp(delP,"1% drop in Voltage decreases power input by(%)");
//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

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

Scilab code Exa 2.3 Increase in generation

```
//exa 2.3
clc;clear;close;
format('v',6);
L=400;///MW///total load
delPD=50;//MW//increase in demand
//dC1/dP1=0.2*P1+30
//dC2/dP2=0.15*P2+40
twoC1=0.2;//from above equation
twoC2=0.15;//from above equation
delP1_by_delPD=(1/twoC1)/(1/twoC1+1/twoC2);
delP2_by_delPD=(1/twoC2)/(1/twoC1+1/twoC2);
delP1=delP1_by_delPD*delPD;//MW
disp(delP1,"Increase in generation of unit1(MW) : ");
delP2=delP2_by_delPD*delPD;//MW
disp(delP2,"Increase in generation of unit2(MW) : ");
format('v',7);
P1=L/2+delP1;//load on unit 1
disp(P1,"Total load on unit1(MW) : ");
P2=L/2+delP2;//load on unit 2
disp(P2,"Total load on unit2(MW) : ");
format('v',6);
disp("Checking incremental cost :");
dC1_by_dP1=0.2*P1+30;//Rs./MWh
disp(dC1_by_dP1,"Incremental cost of unit 1(Rs./MWh) : ");
dC2_by_dP2=0.2*P2+30;//Rs./MWh
disp(dC2_by_dP2,"Incremental cost of unit 2(Rs./MWh) : ");
disp("Conclusion : Cost are same(Approximately).");
//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

```
//exa 2.5
clc;clear;close;
format('v',8);
I1=0.8;//p.u.
I2=1;//p.u.
Za=0.04+%i*0.12;//p.u.
Zb=0.03+%i*0.1;//p.u.
Zc=0.03+%i*0.12;//p.u.
V=1;//p.u.
//Solution :
V1=V+(I1+I2)*Za+I1*(Zb);//p.u.
V2=V+(I1+I2)*Za+I2*(Zc);//p.u.
P1=real(I1*V1);//p.u.
P2=real(I2*V2);//p.u.
fi1=atan(imag(V1),real(V1));
fi2=atan(imag(V2),real(V2));
disp("Loss Coefficients are : ")
B11=[real(Za)+real(Zb)]/[abs(V1)^2*cos(fi1)^2];//p.u
    .
disp(B11,"B11(p.u.) : ");
B22=[real(Za)+real(Zc)]/[abs(V2)^2*cos(fi2)^2];//p.u
    .
disp(B22,"B22(p.u.) : ");
B12=[real(Za)]/[abs(V1)*abs(V2)*cos(fi1)*cos(fi2)];
    //p.u.
disp(B12,"B12(p.u.) : ");
PL=P1^2*B11+P2^2*B22+2*P1*P2*B12;//p.u.
format('v',10);
disp(PL,"Transmission Loss(p.u.) : ");
//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

```
//exa 2.7
clc;clear;close;
format('v',8);
Za=0.03+%i*0.09;//p.u.
Ia=1.5-%i*0.4;//p.u.
Zb=0.10+%i*0.30;//p.u.
Ib=0.5-%i*0.2;//p.u.
Zc=0.03+%i*0.09;//p.u.
Ic=1-%i*0.1;//p.u.
Zd=0.04+%i*0.12;//p.u.
Id=1-%i*0.2;//p.u.
Ze=0.04+%i*0.12;//p.u.
Ie=1.5-%i*0.3;//p.u.
V=1;//p.u.
base=100;//MVA
//Solution
//Currents of load
IL1=0.4;//p.u.
IL2=0.6;//p.u.
//Current distribution factors :
Na1=1;Na2=0;
Nb1=0.6;Nb2=-0.4;
Nc1=0;Nc2=1;
Nd1=0.4;Nd2=0.4;
Ne1=0.6;Ne2=0.6;
//Bus Voltages
V1=V+Ia*Za;//p.u.
V2=V-Ib*Zb+Ic*Zc;//p.u.
//Phase Angles
theta1=atand(imag(Ia),real(Ia));//degree
theta2=atand(imag(Ic),real(Ic));//degree
//Power Factors :
```

```
cos_fi1=cosd(atand(imag(V1),real(V1))-theta1);//source 1 power factor
cos_fi2=cosd(atand(imag(V2),real(V2))-theta2);//source 2 power factor
disp("Loss formula Coefficients in p.u. :")
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.
disp(B11,"B11(p.u) : ");
format('v',7);
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.
disp(B22,"B22(p.u) : ");
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.
disp(B12,"B12(p.u) : ");
//Converting p.u. to actual value
format('v',10);
disp("Loss formula Coefficients in MW^-1 :")
B11=B11/base;//MW^-1
disp(B11,"B11(MW^-1) : ");
format('v',9);
B22=B22/base;//MW^-1
disp(B22,"B22(MW^-1) : ");
B12=B12/base;//MW^-1
disp(B12,"B12(MW^-1) : ");
//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

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

Scilab code Exa 2.9 Saving in Rs per hour

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

```
//dC1/dP1*L1=dC2/dP2*L2
P2=((0.2*P1+22)*L1-30)/0.15;//MW
P=P1+P2-B11*P1^2;//MW//Total Load
//dC1/dP1=dC2/dP2; neglecting transmission loss
clear('P2');//for recalculation
//0.2*P1-0.15*P2-8=0;///eqn(1)
//P1=0.75*P2+40;//P1+P2-B11*P1^2-P=0;//eqn(2)
//1.75*P2-B11*P1^2=P-40
Eqn=[-B11 1.75 40-P];
P2=roots(Eqn);
P2=P2(2);//MW//neglecting higher value
P1=0.75*P2+40;//MW
dC1=integrate('0.2*P+22','P',100,P1);//Rs.//Additional Cost plant1
dC2=integrate('0.15*P+30','P',200,P2);//Rs.//Decreased Cost plant2
dC=dC1+dC2;//Rs./hour//Net change in cost
disp(dC,"Taking transmission loss in account, Net saving per hour in fuel cost(Rs,/hour)");
//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

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

```
P1(1)=0;
P2=0;
for i=2:1:10
    P1(i)=(0.2+0.001*P2(i-1))/0.006;
    P2(i)=(0.4+0.001*P1(i))/0.0088;
    if  P1(i)==P1(i-1) then
break;
    end
end
P1=P1(i);//MW
disp(P1,"Generation P1(MW) : ");
P2=P2(i);//MW
disp(P2,"Generation P2(MW) : ");
format('v',4);
PL=B11*P1^2+2*B12*P1*P2+B22*P2^2;//MW
disp(PL,"Transmission Loss(MW) : ");
format('v',5);
Pr=P1+P2-PL;//MW
disp(Pr,"Received Power(MW) : ");
```

Scilab code Exa 2.11 Cost Characteristics

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

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

Scilab code Exa 2.12 Daily Operating Schedule

```
//exa 2.12
clc;clear;close;
format('v',7);
//C1=7700+52.8*P1+5.5*10^-3*P1^2;//Rs./hour
//C2=2500+15*P2+0.05*P2^2;//Rs./hour
a1=7700;a2=2500;
b1=52.8;b2=15;
c1=5.5*10^-3;c2=0.05;
P1=poly(0,'P1');
P2=poly(0,'P2');
dC1bydP1=52.8+2*5.5*10^-3*P1;
dC2bydP2=15+2*0.05*P2;
disp("For 1200 MW Load :");
P=1200;//MW
//Let loads of unit are P1 & 1200-P1
//Economical Loading dC1/dP1=dC2/dP2
eqn=52.8+2*5.5*10^-3*P1-15-2*0.05*(1200-P1);
P1=roots(eqn);//MW
P2=1200-P1;//MW
disp(P1,"P1(MW) : ");
disp(P2,"P2(MW) : ");
disp("For 900 MW Load :");
P=900;//MW
clear('P1','P2');
P1=poly(0,'P1');
P2=poly(0,'P2');
//Let loads of unit are P1 & 900-P1
```

```
//Economical Loading dC1/dP1=dC2/dP2
eqn=52.8+2*5.5*10^-3*P1-15-2*0.05*(900-P1);
P1=roots(eqn);//MW
P2=900-P1;//MW
disp(P1,"P1(MW) : ");
disp(P2,"P2(MW) : ");
disp("For 500 MW Load :");
P=500;//MW
clear('P1','P2');
P1=poly(0,'P1');
P2=poly(0,'P2');
//Let loads of unit are P1 & 500-P1
//Economical Loading dC1/dP1=dC2/dP2
eqn=52.8+2*5.5*10^-3*P1-15-2*0.05*(500-P1);
P1=roots(eqn);//MW
P2=500-P1;//MW
//Minimum load is 200MW
if P1<200 then
    P2=P1+P2
    P1=0;
end
disp(P1,"P1(MW) : ");
disp(P2,"P2(MW) : ");
format('v',10);
C=(2500+15*P2+0.05*P2^2)*10;//Rs.//Operating cost
    for 10 hour
disp(C,"Operating cost for 10 hour(Rs.)");
disp("Other option : ");
P1=200;//MW
P2=300;//MW
disp(P1,"P1(MW) : ");
disp(P2,"P2(MW) : ");
C1=7700+52.8*P1+5.5*10^-3*P1^2;//Rs./hour
C2=2500+15*P2+0.05*P2^2;//Rs./hour
C=10*(C1+C2);//Rs.//Operating cost for 10 hour
disp(C,"Operating cost for 10 hour(Rs.)");
```

Scilab code Exa 2.13 Cost of generation

```
//exa 2.13
clc;clear;close;
format('v',10);
//C1=2000+20*P1+0.05*P1^2;//Rs./hour
//C2=2750+26*P2+0.03091*P2^2;//Rs./hour
P1=350;//MW
P2=550;//MW
C1=2000+20*P1+0.05*P1^2;//Rs./hour
C2=2750+26*P2+0.03091*P2^2;//Rs./hour
C=C1+C2;//Rs./hour
disp(C,"(a) Total Cost(Rs./hour)");
P=P1+P2;//MW//Total Load
P1=poly(0,'P1');
P2=poly(0,'P2');
dC1bydP1=20+2*0.05*P1;
dC2bydP2=26+2*0.03091*P2;
disp("(b) For Economic Scheduling")
format('v',7);
//dC1/dP1=dC2/dP2 for economic sheduling
//Let loads of unit are P1 & P-P1
eqn=20+2*0.05*P1-26-2*0.03091*(P-P1);
P1=roots(eqn);//MW
P2=P-P1;//MW
disp(P2,P1,"Loads P1 & P2 in MW are : ");
C1=2000+20*P1+0.05*P1^2;//Rs./hour
C2=2750+26*P2+0.03091*P2^2;//Rs./hour
Cnew=C1+C2;//Rs./hour
disp(Cnew,"Total Cost(Rs./hour)");
saving=C-Cnew;//Rs./hour
disp(saving,"Total saving(Rs./hour)");
format('v',5);
Lt=P1-350;//MW//Tie line load
```

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

Scilab code Exa 2.14 Extra Ooperating Cost

```
//exa 2.14
clc;clear;close;
format('v',7);
//C=5000+450*P+0.5*P^2;//Rs./hour
e1=+2;//%//error
e2=-2;//%//error
P=200;//MW//Total Load
//Considering error
P1=poly(0,'P1');
P2=poly(0,'P2');
C1=(5000+450*P+0.5*P1^2)*0.98;//Rs./hour
C2=(5000+450*P+0.5*P2^2)*1.02;//Rs./hour
//Let loads of unit are P1 & P-P1
//dC1/dP1=dC2/dP2 for economic sheduling
eqn=450*0.98+2*0.5*P1*0.98-450*1.02-2*0.5*(P-P1)
    *1.02;
P1=roots(eqn);//MW
P2=P-P1;//MW
//if no instrumention error
C1=(5000+450*P1+0.5*P1^2)*0.98;//Rs./hour
C2=(5000+450*P2+0.5*P2^2)*1.02;//Rs./hour
C=C1+C2;//Rs./hour
//Due to intrumentation error
P1=P/2;//MW
P2=P/2;//MW
C1=(5000+450*P1+0.5*P1^2)*0.98;//Rs./hour
C2=(5000+450*P2+0.5*P2^2)*1.02;//Rs./hour
Cerr=C1+C2;//Rs./hour
Cextra=Cerr-C;//Rs,/hour
disp(Cextra,"Extra operating cost(Rs./hour)");
```

Scilab code Exa 2.15 Find Optimum Scheduling

```
//exa 2.15
clc;clear;close;
format('v',7);
P1=poly(0,'P1');
P2=poly(0,'P2');
P3=poly(0,'P3');
Q1=0.002*P1^2+0.86*P1+20;//tons/hour
Q2=0.004*P2^2+1.08*P2+20;//tons/hour
Q3=0.0028*P3^2+0.64*P3+36;//tons/hour
Pmax=120;//MW
Pmin=36;//MW
P=200;//MW
C=500;//Rs./ton
//C1=C*Q1;C2=C*Q2;C3=C*Q3;//Rs./ton
dC1bydP1=2*P1+430;//Rs./hour
dC2bydP2=4*P2+540;//Rs./hour
dC3bydP3=2.8*P3+320;//Rs./hour
//P1+P2+P3=P
A1=[1 1 1];//Coefficient Matrix
B1=[P];//Coefficient Matrix
//For minimal cost above 3 equation should be equal
//eqn1=2*P1-4*P2+430-540;
//eqn2=4*P2-2.8*P3-320+540;
A2=[0 4 -2.8];//Coefficient Matrix
B2=[-540+320];//Coefficient Matrix
//eqn3=-2*P1+2.8*P3+320-430;
A3=[-2 0 2.8];//Coefficient Matrix
B3=[430-320];//Coefficient Matrix
//solving by matrix method
A=[A1;A2;A3];//Coefficient Matrix
B=[B1;B2;B3];//Coefficient Matrix
X=A^-1*B;//Solution Matrix
```

```
P1=X(1);//MW
P2=X(2);//MW
P3=X(3);//MW
Pmax=120;//MW
Pmin=36;//MW
if P2<Pmin then
   P2=Pmin;//MW
end;
//P1+P3=P-P2//eqn(4)
A1=[1 1];//Coefficient Matrix
B1=[P-P2];//Coefficient Matrix
//eqn3=-2*P1+2.8*P3+320-430;
A2=[-2 2.8];//Coefficient Matrix
B2=[430-320];//Coefficient Matrix
//solving by matrix method
A=[A1;A2];//Coefficient Matrix
B=[B1;B2];//Coefficient Matrix
X=A^-1*B;//Solution Matrix
P1=X(1);//MW
P3=X(2);//MW
disp("According to optimum scheduling, Load
   distriution is :");
disp(P1,"P1(MW) : ");
disp(P2,"P2(MW) : ");
disp(P3,"P3(MW) : ");
```

Scilab code Exa 2.16 Heat inputs and savings

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

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

Scilab code Exa 2.17 Find Optimum Scheduling

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

```
A2=[2*0.0013 -2*0.0019 0];//Coefficient Matrix
B2=[7.8-6.5];//Coefficient Matrix
//Equating eqn(2) & (3)
A3=[0 2*0.0019 -2*0.005];//Coefficient Matrix
B3=[8.1-7.8];//Coefficient Matrix
//Solution By Matrix method
A=[A1;A2;A3];//Coefficient Matrix
B=[B1;B2;B3];//Coefficient Matrix
X=A^-1*B;//Solution Matrix
P1=X(1);//MW
P2=X(2);//MW
P3=X(3);//MW
disp("(b) According to optimum scheduling, Load distriution is :");
disp(P1,"P1(MW) : ");
disp(P2,"P2(MW) : ");
disp(P3,"P3(MW) : ");
//Part(c)
disp("(c) Optimum scheduling : ");
P1max=600;//MW
P1min=100;//MW
P2max=400;//MW
P2min=50;//MW
P3max=200;//MW
P3min=50;//MW
if P2<P2max&P2>P2min then
    disp("P2 is within maximum and minimum limits.");
    P1=P1max;//MW
    P3=P3min;//MW
    P2=P-P1-P3;//MW
end;
//Lambda=dC2/dP2 as P2 is niether maximum limit nor minimum limit.
dC2BydP2=7.8+2*0.0019*P2;//Rs./MWh
lambda=dC2BydP2;//Rs./MWh
dC1BydP1=6.5+2*0.0013*P1;//Rs./MWh
dC3BydP3=8.1+2*0.005*P3;//Rs./MWh
```

```
if dC1BydP1<lambda then
    disp("Condition for P1 satisfied.");
end;
if dC3BydP3>lambda then
    disp("Condition for P3 satisfied.");
end;
disp("Load distribution is : ");
disp(P1,"P1(MW) : ");
disp(P2,"P2(MW) : ");
disp(P3,"P3(MW) : ");
```

Scilab code Exa 2.18 `Transmission Loss`

```
//exa 2.18
clc;clear;close;
format('v',6);
Bmn=[0.0676 0.00953 -0.00507
0.00953 0.0521 0.00901
-0.00507 0.00901 0.0294];//Loss Coefficient
Bno=[-0.0766;0.00342;0.0189];//Loss Coefficient
Boo=0.04357;//Loss Coefficient
P1=107.9;//MW
P2=50;//MW
P3=60;//MW
//solution :
PL=[P1 P2 P3]*Bmn+[P1 P2 P3]*Bno+Boo;//MW
PL=sum(-PL);//MW
disp(PL,"Transmission Loss(MW)");
//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`

```
//exa 2.19
clc;clear;close;
format('v',6);
//lambda1=0.1*P1+20;//Rs./MWh
//lambda2=0.12*P2+16;//Rs./MWh
P=180;//MW
//Let loads are P1 & P-P1
//Economical loading lambda1=lambda2
P1=poly(0,'P1');P2=poly(0,'P2');
eqn=0.1*P1+20-0.12*(P-P1)-16;
P1=roots(eqn);//MW
P2=P-P1;//MW
disp(P1,"Load P1(MW) : ");
disp(P2,"Load P2(MW) : ");
```

Scilab code Exa 2.20 `Find the load division`

```
//exa 2.20
clc;clear;close;
format('v',6);
//F1=0.004*P1^2+2*P1+80;//Rs./hr
//F2=0.006*P2^2+1.5*P2+100;//Rs./hr
P=250;//MW
P1=poly(0,'P1');P2=poly(0,'P2');
dF1bydP1=2*0.004*P1+2;
dF2bydP2=2*0.006*P2+1.5;
//Let loads are P1 & P-P1
//Economical loading lambda1=lambda2
eqn=2*0.004*P1+2-2*0.006*(P-P1)-1.5;
P1=roots(eqn);//MW
P2=P-P1;//MW
disp(P1,"Load P1(MW) : ");
disp(P2,"Load P2(MW) : ");
```

Scilab code Exa 2.21 Minimum cost of generation

```
//exa 2.21
clc;clear;close;
format('v',8);
//F1=(8*P1+0.024*P1^2+80)*10^6;//Btu./hr
//F2=(6*P2+0.04*P2^2+120)*10^6;//Btu./hr
Pmax=100;//MW
Pmin=10;//MW
C=2.5;//Rs./million Btu
//C1=2.5*F1/10^6
//C2=2.5*F2/10^6
//For Maximum Load of 100 MW
P1=poly(0,'P1');P2=poly(0,'P2');
dC1bydP1=8*2.5+2.5*2*0.024*P1;
dC2bydP2=6*2.5+2.5*2*0.04*P2;
//Let loads are P1 & Pmax-P1
//Economical loading lambda1=lambda2
eqn=8*2.5+2.5*2*0.024*P1-6*2.5-2.5*2*0.04*(Pmax-P1);
P1=roots(eqn);//MW
P2=Pmax-P1;//MW
C1=2.5*((8*P1+0.024*P1^2+80)*10^6)/10^6;//Rs./hour
C2=2.5*((6*P2+0.04*P2^2+120)*10^6)/10^6;//Rs./hour
C100=(C1+C2)*12;//Rs.(Total cost of 12 hours on 100 MW load)
//For Maximum load of 50 MW
//Let loads are P1 & Pmax-P1
//Economical loading : lambda1=lambda2
Pmax1=50;//MW
clear('P1','P2');
P1=poly(0,'P1');P2=poly(0,'P2');
eqn=8*2.5+2.5*2*0.024*P1-6*2.5-2.5*2*0.04*(Pmax1-P1);
P1=roots(eqn);//MW
```

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

Scilab code Exa 2.22 `Find Optimum Scheduling`

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

```
dF1bydP1=2*0.05*P1+21.5;
dF2bydP2=2*0.1*P2+27;
dF2bydP3=2*0.07*P3+16;
//Solving equation :
A=[2*0.05 0 0;0 2*0.1 0;0 0 2*0.07];
B=[lambda-21.5;lambda-27;lambda-16];
X=A^-1*B;
P1=X(1);//MW
P2=X(2);//MW
P3=X(3);//MW
if P2<Pmin then
    P2=Pmin;
end
P1plusP3=PT-P2;//MW
//dF1/dP1=dF3/dP3
//Let loads are P1 & P1plusP3-P1
clear('P1','P3');
P1=poly(0,'P1');P3=poly(0,'P3');
 eqn=2*0.05*P1+21.5-2*0.07*(P1plusP3-P1)-16;
 P1=roots(eqn);//MW
 P3=P1plusP3-P1;//MW
 disp("Optimum scheduling :");
 disp(P3,P2,P1,"Loads P1, P2 & P3 in MW are :");
 F1=0.05*P1^2+21.5*P1+800;//Rs./hr
F2=0.1*P2^2+27*P2+500;//Rs./hr
F3=0.07*P3^2+16*P3+900;//Rs./hr
C=F1+F2+F3;//Rs/hour
disp(C,"For this schedule, total cost per hour(Rs./hour)");
```

Scilab code Exa 2.23 Generation schedule and load demand

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

```
//dF1/dP1=0.025*P1+15;//
//dF2/dP2=0.05*P2+20;//
PL=15.625;//MW
P1=125;//MW
lambda=24;//Rs. per MWh
B11=PL/P1^2;//Coefficient Loss
//dF2/dP2*L2=lambda
P2=poly(0,'P2');
L2=1;//penalty factor
eqn=(0.05*P2+20)*L2-lambda;
P2=roots(eqn);//MW
//PL=B11*P1^2
P1=poly(0,'P1');
dPLbydP1=2*B11*P1;
L1=1/(1-dPLbydP1);//penalty factor
eqn=(0.025*P1+15)-lambda/L1
P1=roots(numer(eqn));//MW
disp(P2,P1,"Generation P1 & P2 in MW are ");
PL=B11*P1^2;//MW
LD=P1-PL+P2;//MW
disp(LD,"Load Demand(MW) :");
```

Scilab code Exa 2.24 `Optimum Schedule and total generation`

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

```
L2=1;//penalty factor
eqn=(0.04*P2+20)*L2-lambda;
P2=roots(eqn);//MW
//PL=B11*P1^2
P1=poly(0,'P1');
dPLbydP1=2*B11*P1;
L1=1/(1-dPLbydP1);//penalty factor
eqn=(0.02*P1+16)-lambda/L1
P1=roots(numer(eqn));//MW
disp(P2,P1,"Generation P1 & P2 in MW are ")
PL=B11*P1^2;//MW
LD=P1-PL+P2;//MW
disp(LD,"Load Demand(MW) :");
```

Chapter 3

Hydrothermal Coordination

Scilab code Exa 3.1 MW rating

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

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

Scilab code Exa 3.2 `Capacity of hydro plant and steel plant`

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

Scilab code Exa 3.3 `Water Used and operating cost`

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

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

Scilab code Exa 3.4 Load on plant and cost of water

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

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

Chapter 4

Modelling of turbine generators and automatic controllers

Scilab code Exa 4.1 Shared load and power factor

```
//Exa 4.1
clc;clear;close;
format('v',8);
kVA=4000;//kVA//rating
f1_nl=50;//Hz(No load frequency of machine1)
f1_fl=47.5;//Hz(No load frequency of machine1)
f2_nl=50;//Hz(No load frequency of machine2)
f2_fl=48;//Hz(No load frequency of machine2)
L=6000;//kW(Load)
L1=poly(0,'L1');//Load of machine1
//f1_nl-(f1_nl-f1_fl)*L1/kVA=f1_nl-(f2_nl-f2_fl)*L2/kVA where L2=L-L1
L1=(f2_nl-f2_fl)*L/[(f1_nl-f1_fl)+(f2_nl-f2_fl)];//kW
L2=L-L1;//kW
disp("Part(a)");
disp(L1,"Load supplied by first machine(kW)");
disp(L2,"Load supplied by second machine(kW)");
disp("Part(b)");
```

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

Scilab code Exa 4.2 Current Power factor and emf

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

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

Scilab code Exa 4.3 Synchronising power

```
//Exa 4.3
clc;clear;close;
format('v',5);
P=5;//MVA
V=1000;//V
speed=1500;//rpm//speed
ns=speed/60;//rps
f=50;//Hz
pf=0.8;//Power factor Lagging
Xs=20;//%//synchronous reluctance
Xs=Xs/100;///p.u.
disp("Part(a)");
V=1;//p.u.//on no load
E=1;//p.u.//on no load
Ps=V*E/Xs;//p.u.
Ps=Ps*P;//MW per elect. radian
Ps=Ps*1000;//kW per elect. radian
//1 mech. radian=%pi/90 elect. radian
```

```
Ps=Ps*%pi/90;//kW per mech. degree
disp(Ps,"Synchronising power per mech. degree(kW)");
d=0.5;//degree////displacement
Ts=Ps*1000*d/2/%pi/ns;//N-m
format('v',6);
disp(Ts,"Synchronising torque(N-m)");
disp("Part(b)");
theta=acosd(pf);//degree
E=V+(cosd(theta)-%i*sind(theta))*%i*Xs;//p.u.
Ps=V*E/Xs;//p.u.
Ps=Ps*P;//MW per elect. radian
Ps=Ps*1000;//kW per elect. radian
//1 mech. radian=%pi/90 elect. radian
Ps=Ps*%pi/90;//kW per mech. degree
Ps=abs(Ps);//kW per mech. degree
disp(Ps,"Synchronising power per mech. degree(kW)");
d=0.5;//degree////displacement
Ts=abs(Ps)*1000*d/2/%pi/ns;//N-m
disp(Ts,"Synchronising torque(N-m)");
//Answer in the textbook is not accurate.
```

Scilab code Exa 4.4 Synchronising power and torque

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

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

Scilab code Exa 4.5 Load current and power factor

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

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

Scilab code Exa 4.6 Inertia Constant

```
//Exa 4.6
clc;clear;close;
format('v',7);
G=200;//MVA
H=6;//MJ/MVA///Inertia Constant
V=11;//kV
f=50;//Hz
L1=120;//MW
L2=160;//MW

//Calculation
disp("Part(a)");
Es=G*H;//MJ////Stored Energy
disp(Es,"Stored energy(MJ)");
disp("Part(b)");
Pa=L1-L2;//MW
M=G*H/180/f;//MJ-sec/elect.deg.
alfa=-Pa/M;//elect.deg./sec^2///Retardation
```

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

Chapter 5

Frequency Control

Scilab code Exa 5.1 Change in power output

```
//Example 5.1
clc;clear;close;
P=100;//MW
drop=4;//%(No load to full load drop)
f=50;//Hz
disp("Part(i)");
p=1;//MW(For calculating per unit MW)
R=(drop/100)*f/p;//Hz/p.u.MW
disp(R,"Speed regulation in Hz/p.u.MW");
R=(drop/100)*f/P;//Hz/MW
disp(R,"Speed regulation in Hz/MW");
disp("Part(ii)");
del_f=-0.1;//Hz(Frequency drop)
delP=-1/R*del_f;//MW(Change in power output)
disp(delP,"Change in power output(MW)");
```

Scilab code Exa 5.2 Frequency Deviation

```
//Example 5.2
clc;clear;close;
format('v',6);
P=100;//MVA
f=50;//Hz
H=5;//kW-sec/kVA(Constant)
delP=50;//MW(Increased Load)
td=0.5;//s(Time delay)
P=P/1000;//kVA
KE=P*H;//kW-sec
delP=delP/1000;//kW(Increased Load)
KE_loss=delP*td;//kW-s
f_new=sqrt((KE-KE_loss)/KE)*f;//Hz
f_dev=(f-f_new)/f*100;//%(Frequency deviation)
disp(f_dev,"Frequency deviation(%)");
```

Scilab code Exa 5.3 `Value of R`

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

Scilab code Exa 5.4 Static Frequency Drop

```
//Example 5.4
clc;clear;close;
format('v',8);
f=50;//Hz
R=2;//Hz/pu MW
Pr=10000;//MW(Rated Capacity)
P=Pr/2;//MW(Operating Power)
delP=2;//%(Load Increase)
del_f=f*1/100;//Hz(1% change in frequency)
del_PL=P*1/100;//MW(1% change in load)
//Rate of change of load with frequency :
D=del_PL/del_f;//MW/Hz
D=D/Pr;//p.u. MW/Hz
//Frequency response characteristic :
Beta=D+1/R;//p.u. MW/Hz
M=delP/100*P;//MW
M=M/Pr;//p.u. MW
del_fo=-M/Beta;//Hz
disp(del_fo,"Static frequency drop(Hz)")
R=%inf;
Beta=D+1/R;//p.u. MW/Hz
del_fo=-M/Beta;//Hz
disp(del_fo,"If speed governer loop is open,
   frequency drop(Hz)")
```

Scilab code Exa 5.5 Primary ALFC looop parameter

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

```
C=10000;//MW(Control area capacity)
P=5000;//MW
H=5;//s
R=3;//Hz/pu MW
f=50;//Hz
del_f=f*1/100;//Hz
del_PL=P*1/100;//MW
D=del_PL/del_f;//MW/Hz
D=D/C;//p.u. MW/Hz
//Primary ALFC loop parameters :
Kp=1/D;//Hz/p.u. MW
Tp=2*H/f/D;//s
disp("Primary ALFC loop parameters :")
disp(Kp,"Kp(Hz/p.u. MW)");
disp(Tp,"Tp(seconds)");
```

Scilab code Exa 5.6 Increased Generation

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

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

Scilab code Exa 5.7 Frequency Deviation

```
//Example 5.7
clc;clear;close;
format('v',5);
G=100;//MVA
f=50;//Hz
n=3000;//rpm
L=25;//MW//Load
td=0.5;//sec
H=4.5;//MW-sec/MVA
//Calculation
KE=H*G;//MW-sec////at no load
KE_Loss=L*td;//MW-sec///due to increase in load
f_new=sqrt((KE-KE_Loss)/KE)*f;//Hz
delF=(f-f_new)/f*100;//%////frequency deviation
disp(delF,"Frequency deviation(%)");
```

Scilab code Exa 5.8 Change in step and frequency

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

```
C=4000;//MW
f=50;//Hz
L=2500;//MW//Load
R=2;//Hz/p.u.MW////Speed regulation constant
H=5;//sec////Inertia constant
delPL=2;//%////change in load
delf=1;//%////change in frequency
disp("Part(a)");
D=delPL/delf*L/f;//MW/Hz
D=D/C;//p.u.MW/Hz
Beta=D+1/R;//p.u.MW/Hz
delf0=-0.2;//Hz
M=-(delf0)*Beta;//p.u.MW
M=M*C;//MW
disp(M,"Largest change in step load(MW)");
disp("Part(b)");
Kp=1/D;//Hz/p.u.MW
Tp=2*H/f/D;//sec
Tdash=(R+Kp)/R/Tp;//sec
disp(Tdash,"(R+Kp)/(R*Tp) in seconds = ");
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

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

```
disp("Part(a)");
Ls=80;//MW;//increase in step to load
R=R/100*f;//z/p.u.MW
D=delPL/delf*L/f;//MW/Hz
D=D/C;//p.u.MW/Hz
M=Ls/L;//unitless//for given step load
Kp=1/D;//Hz/p.u.MW
Tp=2*H/f/D;//sec
Tdash1=(R+Kp)/R/Tp;//sec
disp(Tdash1,"(R+Kp)/(R*Tp) in seconds = ");
Tdash2=(R*Kp*M)/(R+Kp);//sec
disp(Tdash2,"(R*Kp*M)/(R+Kp) in seconds = ");
delf0=-Tdash2;//Hz////Static frequency error
disp(delf0,"Static frequency error(Hz)");
disp("Part(b)");
Ki=(1+Kp/R)^2/4/Tp/Kp;//p.u.MW/Hz
disp(Ki,"Critical value of Ki(p.u.MW/Hz)");
```

Scilab code Exa 5.10 Change in step and frequency error

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

```
R=R/100*f;//z/p.u.MW
D=delPL/delf*C/f;//MW/Hz
D=D/C;//p.u.MW/Hz
Kp=1/D;//Hz/p.u.MW
Tp=2*H/f/D;//sec
Gp=Kp/(1+Tp*s);//Transfer function of power system
delFs=-Gp/(1+Gr*Gt*Gp/R);
disp(delFs,"delFs = M/s*");
disp("Part(b)");
delf0_by_M=-Kp/(1+Kp/R);//Hz
delf0=delf/100*f;//Hz
M=delf0/delf0_by_M;//p.u.MW
M=M*C;//MW
disp(M,"Largest step change(MW)");
//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

```
//Example 5.11
clc;clear;close;
format('v',8);
GA=5000;//MW
GB=10000;//MW
R=2;//Hz/p.u.MW////Speed regulation constant
D=0.01;//p.u.MW/Hz
Ls=100;//MW//Load increase
RA=R*GB/GA;//Hz/p.u.MW
DA=D*GA/GB;//p.u.MW/Hz
RB=R;//Hz/p.u.MW
DB=D;//p.u.MW/Hz
Beta_A=DA+1/RA;//p.u.MW/Hz
Beta_B=DB+1/RB;//p.u.MW/Hz
MA=0;//Load increase
```

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

Scilab code Exa 5.12 Change in frequency and tie line power

```
//Example 5.12
clc;clear;close;
format('v',8);
GA=500;//MW
GB=2000;//MW
RA=2.5;//Hz/p.u.MW////Speed regulation constant
RB=2;//Hz/p.u.MW////Speed regulation constant
Ls=20;//MW//Load increase
f=50;//Hz
delL=1;//%////change in load
delf=1;//%////change in frequency
DA=delL/delf*GA/f;//MW/Hz
DA=DA/GB;//p.u.MW/Hz
DB=delL/delf*GB/f;//MW/Hz
DB=DB/GB;//p.u.MW/Hz
RA=RA*GB/GA;//Hz/p.u.MW
Beta_A=DA+1/RA;//p.u.MW/Hz
Beta_B=DB+1/RB;//p.u.MW/Hz
disp("Part(a)");
MA=Ls/GB;//unitless
MB=0;//unitless
delf0=-MA/(Beta_A+Beta_B);//Hz
disp(delf0,"Change in frequency(Hz)");
delPAB=-Beta_B*MA/(Beta_B+Beta_A);//p.u.MW
delPAB=delPAB*GB;//MW
```

```
disp(delPAB,"Change in tie line power(MW)");
disp("Part(b)");
MB=Ls/GB;//unitless
MA=0;//unitless
delf0=-MB/(Beta_A+Beta_B);//Hz
disp(delf0,"Change in frequency(Hz)");
delPAB=Beta_A*MB/(Beta_B+Beta_A);//p.u.MW
delPAB=delPAB*GB;//MW
disp(delPAB,"Change in tie line power(MW)");
```

Scilab code Exa 5.13 Frequency of collision

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

Scilab code Exa 5.14 Frequency at shared load

```
//Example 5.14
clc;clear;close;
format('v',6);
C1=300;//MW
C2=400;//MW
G1=4;//%//droop characteristics of governer
G2=5;//%//droop characteristics of governer
L=600;//MW
f=50;//Hz
//Load on first generator =L1
//Load on second generator =L-L1
//f-G1*f/100*(L1/C1)=f-G2*f/100*(L2/C2)
L1=G2*L/C2/(G1/C1+G2/C2);//MW
L2=L-L1;//MW
disp(L1,"Load on first generator(MW)");
disp(L2,"Load on second generator(MW)");
fLoad=f*(1-L1/C1*G1/100);//Hz
disp(fLoad,"Frequency at load(Hz)");
```

Scilab code Exa 5.15 Change in frequency

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

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

Scilab code Exa 5.16 `Percentage frequency deviation`

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

Scilab code Exa 5.17 `Rate of frequency increase`

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

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

Scilab code Exa 5.18 Primary ALFC looop parameter

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

Scilab code Exa 5.19 Compute the time error

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

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

Scilab code Exa 5.20 Generated output Power and frequency

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

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

Scilab code Exa 5.21 No Load Frequencies

```
//Example 5.21
clc;clear;close;
format('v',6);
C1=300;//MW
C2=400;//MW
G1=4;//%//droop characteristics of governer
G2=6;//%//droop characteristics of governer
L=400;//MW
f=50;//Hz
L1=C1*L/(C1+C2);//MW//Load on 300 MW generator
L2=L*C2/(C1+C2);//MW//Load on 400 MW generator
f01=f*(C1)/(C1-G1/100*L1);//Hz///No load frequency
disp(f01,"No load frequency of 300 MW generator(Hz)"
    );
f02=f*(C2)/(C2-G2/100*L2);//Hz///No load frequency
disp(f02,"No load frequency of 400 MW generator(Hz)"
    );
```

Scilab code Exa 5.22 Generation and transfer of power

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

```
RA=R1/100*f/C1;//Hz/MW
RB=R2/100*f/C2;//Hz/MW
//Let PA= generation at plant A
//PB=2*L-PA will be generation at plant B
//RA*PA=RB*PB
PA=RB*2*L/(RA+RB);//MW
PB=2*L-PA;//MW
disp(PA,"Load generation at plant A(MW)");
disp(PB,"Load generation at plant B(MW)");
Pt=PA-L;//MW///Power transfer
disp(Pt,"Power transfer from A to B(MW)");
```

Scilab code Exa 5.23 Voltage Boost Needed

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

Scilab code Exa 5.24 Phase angle and pu real and active

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

```
Z=3+%i*9;//%///impedence
Z=Z/100;//p.u.///Impedence
I=1;//p.u.
IZ=Z;//p.u.
disp("Part(a)");
//2*I^2-2*cos(del)=[abs(IZ)]^2
cos_del=acosd((2*I^2-[abs(IZ)]^2)/2);//degree
disp(cos_del,"Phase angle between two station(degree)");
angle_abc=87.277;///degree
theta=180-angle_abc-atand(imag(IZ)/real(IZ));//degree
Preal=I^2*cosd(theta);//p.u.
disp(Preal,"Real power transfer(p.u.)");
Preactive=I^2*sind(theta);//p.u.
disp(Preactive,"Reactive power transfer(p.u.)");
disp("Part(b)");
//1.05^2+1^2-2*1.05*cos(del)=[abs(IZ)]^2
cos_del=acosd((1.05^2+1^2-[abs(IZ)]^2)/2/1.05);//degree
disp(cos_del,"Phase angle between two station(degree)");
angle_dbc=60.53;///degree
theta=atand(imag(IZ)/real(IZ))-angle_dbc//degree
Preal=I^2*cosd(theta);//p.u.
disp(Preal,"Real power transfer(p.u.)");
Preactive=I^2*sind(theta);//p.u.
disp(Preactive,"Reactive power transfer(p.u.)");
//Answer in the textbook is not accurate.
```

Chapter 6

Reactive power control

Scilab code Exa 6.1 `Voltage and power factor`

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

Scilab code Exa 6.2 Voltage and power factor

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

Scilab code Exa 6.3 Find ABCD Parameters

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

```
z=Z/l;//ohm/km
y=Y/l;//Siemens/km
re=l*sqrt(z*y);//
Zc=sqrt(z/y);//ohm
disp("Part(a) A,B,C,D parameters are : ");
A=cosh(re);//unitless
D=A;//unitless
B=Zc*sinh(re);//ohm
C=sinh(re)/Zc;//unitless
A_mag=abs(A);//unitless
A_angle=atand(imag(A)/real(A));//degree
B_mag=abs(B);//ohm
B_angle=atand(imag(B)/real(B));//degree
C_mag=abs(C);//unitless
C_angle=atand(imag(C)/real(C));//degree
C_angle=C_angle+180;//degree(Converting -ve to +ve angle)
D_mag=abs(D);//unitless
D_angle=atand(imag(D)/real(D));//degree
disp(A_mag,"Magnitude of A : ");
format('v',5);
disp(A_angle,"Angle of A(degree) : ");
format('v',7);
disp(B_mag,"Magnitude of B(ohm) : ");
format('v',6);
disp(B_angle,"Angle of B(degree) : ");
format('v',8);
disp(C_mag,"Magnitude of C : ");
format('v',6);
disp(C_angle,"Angle of C(degree) : ");
format('v',7);
disp(D_mag,"Magnitude of D : ");
format('v',5);
disp(D_angle,"Angle of D(degree) : ");
//60% series compensation
B=B-%i*60/100*abs(Z)*sind(atand(imag(Z),real(Z)));//ohm(considering series compensation=60%)
//For Equivalent pi-circuit
```

```
disp("Part(b) A,B,C,D parameters of compensated line are : ");
Ydash=2/Zc*[(cosh(re)-1)/sinh(re)];//S
A=1+B*Ydash/2;//unitless
D=A;//unitless
C=2*Ydash/2+B*(Ydash/2)^2;//unitless
A_mag=abs(A);//unitless
A_angle=atand(imag(A)/real(A));//degree
B_mag=abs(B);//ohm
B_angle=atand(imag(B)/real(B));//degree
C_mag=abs(C);//unitless
C_angle=atand(imag(C)/real(C));//degree
C_angle=C_angle+180;//degree(Converting -ve to +ve angle)
D_mag=abs(D);//unitless
D_angle=atand(imag(D)/real(D));//degree
format('v',4);
disp(B_mag,"Magnitude of B(ohm) : ");
format('v',6);
disp(B_angle,"Angle of B(degree) : ");
format('v',7);
disp(A_mag,"Magnitude of A : ");
format('v',5);
disp(A_angle,"Angle of A(degree) : ");
format('v',6);
disp(C_mag,"Magnitude of C : ");
format('v',5);
disp(C_angle,"Angle of C(degree) : ");
format('v',7);
disp(D_mag,"Magnitude of D : ");
format('v',5);
disp(D_angle,"Angle of D(degree) : ");
//Answer for some parts are not accurate in the textbook.
```

Scilab code Exa 6.4 Constant of nominal pi circuit

```
//exa 6.4
clc;clear;close;
format('v',6);
l=350;//km(length of line)
Z=180*expm(%i*75*%pi/180);//ohm/phase(Total)
Y=1*10^-3*expm(%i*90*%pi/180);//Siemens/phase(Total)
z=Z/l;//ohm/km
y=Y/l;//Siemens/km
re=l*sqrt(z*y);//
Zc=sqrt(z/y);//ohm
disp("For Uncompensated Line, Constants are :");
B=Z;//ohm//B Parameter
A=1+Z*Y/2;//unitless//A Parameter
D=A;//unitless//D Parameter
C=Y*(1+Z*Y/4);//S//C Parameter
A_mag=abs(A);
A_angle=atand(imag(A)/real(A));//degree
B_mag=abs(B);
B_angle=atand(imag(B)/real(B));//degree
C_mag=abs(C);
C_angle=atand(imag(C)/real(C))+180;//degree
D_mag=abs(D);
D_angle=atand(imag(D)/real(D));//degree
disp(B_angle,B_mag,"Magnitude and Angle(degree) of B (ohm) is ");
disp(A_angle,A_mag,"Magnitude and Angle(degree) of A is ");
disp(D_angle,D_mag,"Magnitude and Angle(degree) of D is ");
format('v',9);
disp(C_mag,"Magnitude of C(S) is ");
format('v',6);
disp(C_angle,"Angle(degree) of C is ");
disp("For Compensated Line, Constants are :");
B=Z-0.6*%i*406;//ohm//B Parameter
A=1+conj(B)*Y/2;//unitless//A Parameter
```

```
D=A;//unitless//D Parameter
C=Y*(1+Z*Y/4);//S//C Parameter
A_mag=abs(A);
A_angle=atand(imag(A)/real(A));//degree
B_mag=abs(B);
B_angle=-atand(imag(B)/real(B));//degree
C_mag=abs(C);
C_angle=atand(imag(C)/real(C))+180;//degree
D_mag=abs(D);
D_angle=atand(imag(D)/real(D));//degree
disp(B_angle,B_mag,"Magnitude and Angle(degree) of B(ohm) is ");
disp(A_angle,A_mag,"Magnitude and Angle(degree) of A is ");
disp(D_angle,D_mag,"Magnitude and Angle(degree) of D is ");
format('v',9);
disp(C_mag,"Magnitude of C(S) is ");
format('v',6);
disp(C_angle,"Angle(degree) of C is ");
```

Scilab code Exa 6.5 `VAR injection ay bus`

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

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

Scilab code Exa 6.6 Capacity of shunt compensation

```
//exa 6.6
clc;clear;close;
format('v',6);
A=0.98*expm(%i*3*%pi/180);//Constant
B=110*expm(%i*75*%pi/180);//ohm/phase
P=50;//MVA
pf=0.8;//lagging
V=132;//kV
//Formula : Pr=|Vs|*|Vr|/|B|*cosd(Beta-delta)-|A|*|Vr|^2/|B|*cosd(Beta-alfa) :
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));
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
Qr=P*0.6-Qr;//MVar//Since load require lagging component
disp(Qr,"(a) Capacity of shunt compensation equipment(MVar) : ");
//part(b)
```

```
//Formula : Pr=|Vs|*|Vr|/|B|*cosd(Beta-delta)-|A|*|Vr|^2/|B|*cosd(Beta-alfa) :
format('v',5);
P=0;//MW
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));
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
Qr=P*0.6-Qr;//MVar//Since load require lagging component
disp(-Qr,"(b) Capacity of shunt compensation equipment(MVar) : ");
```

Scilab code Exa 6.7 Find tap settings

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

Scilab code Exa 6.8 Find tap settings

```
//exa 6.8
clc;clear;close;
format('v',6);
kV1=132;//kV
kV2=33;//kV
kV3=11;//kV
MVA1=75;//MVA
MVA2=50;//MVA
MVA3=25;//MVA
X=0.12;//p.u.
//part(a)
P=60;//MW
V1=125;//kV
V1=V1/kV1;//p.u.
Q=MVA2/MVA1;//p.u.
//V1=Vn+X*Q/Vn
Vn=poly(0,'Vn');
eqn=Vn^2-V1*Vn+X*Q
Vn=roots(eqn);//p.u.
Vn=Vn(1);//p.u.
Vn=Vn*kV1;//kV
k=Vn/kV2;//Transformer ratio
disp(k,"Under Load condition, transformer ratio is "
    );
//part(b)
V1=140;//kV
V1=V1/kV1;//p.u.
Q=MVA3/MVA1;//p.u.
//V1=Vn+X*Q/Vn
Vn=poly(0,'Vn');
eqn=Vn^2-V1*Vn+X*Q
Vn=roots(eqn);//p.u.
```

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

Scilab code Exa 6.9 Settings of tap changes

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