EE523 Assignment 7
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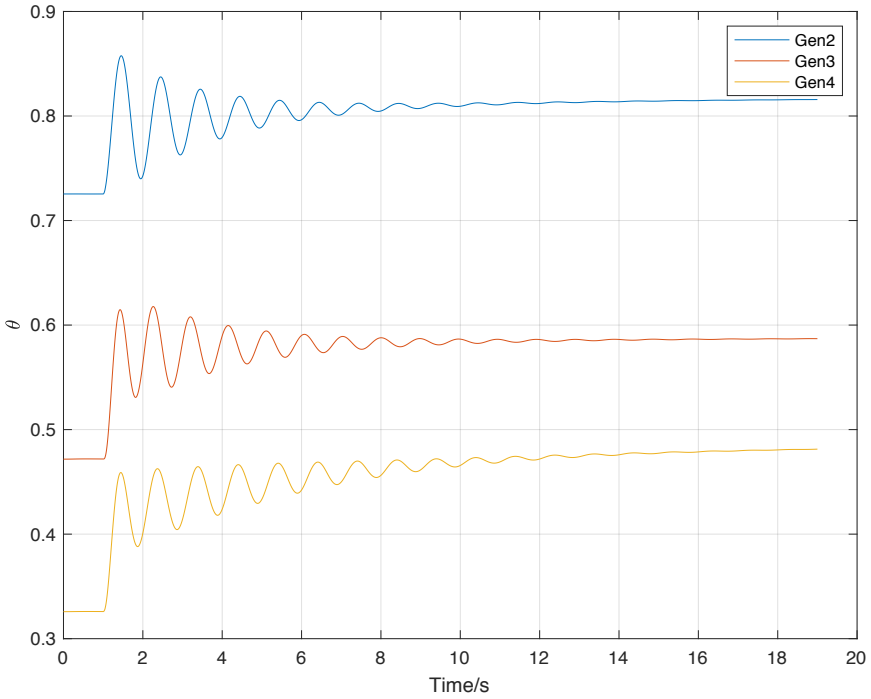
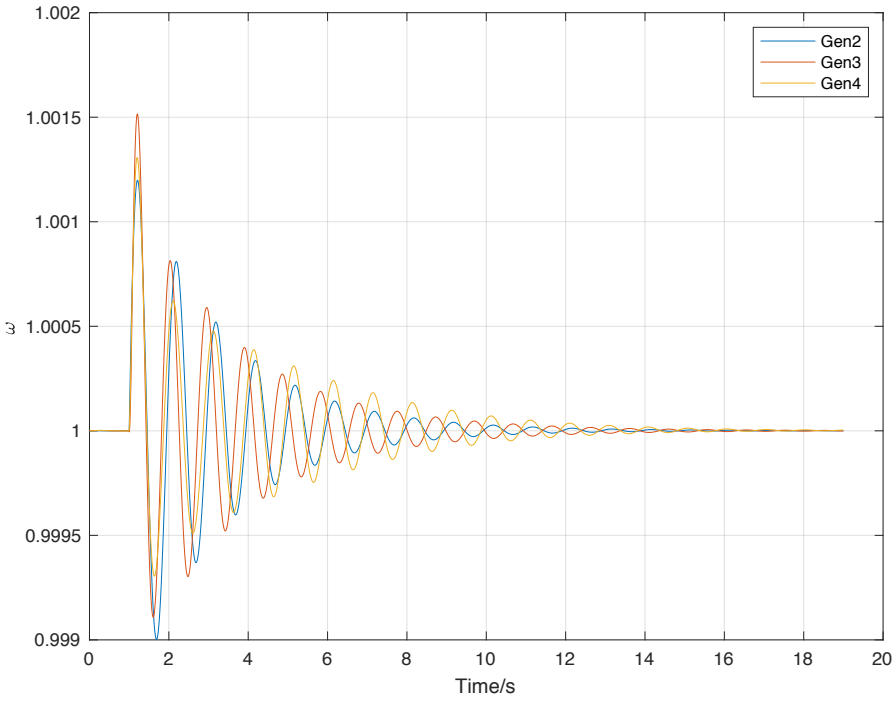
05/01/2020

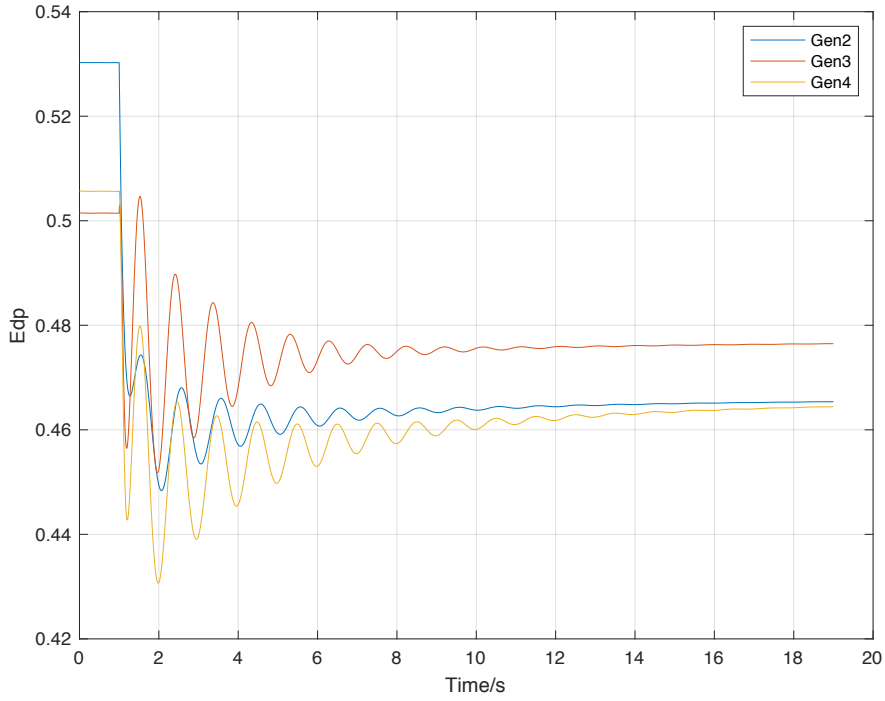
Assume the system parameters as from Homework 6. We want to study a fault on one of the transmission lines between buses 7 and 8. Assume a solid fault in the middle of the line. Assume Euler integration method with a step size of 1 msec. Repeat for each of Type 1, Type 2 and Type 3 models from your small-signal stability homework solutions.
1) For tc = 3 cycles, check if the system is stable.
2) Find the critical clearing time.

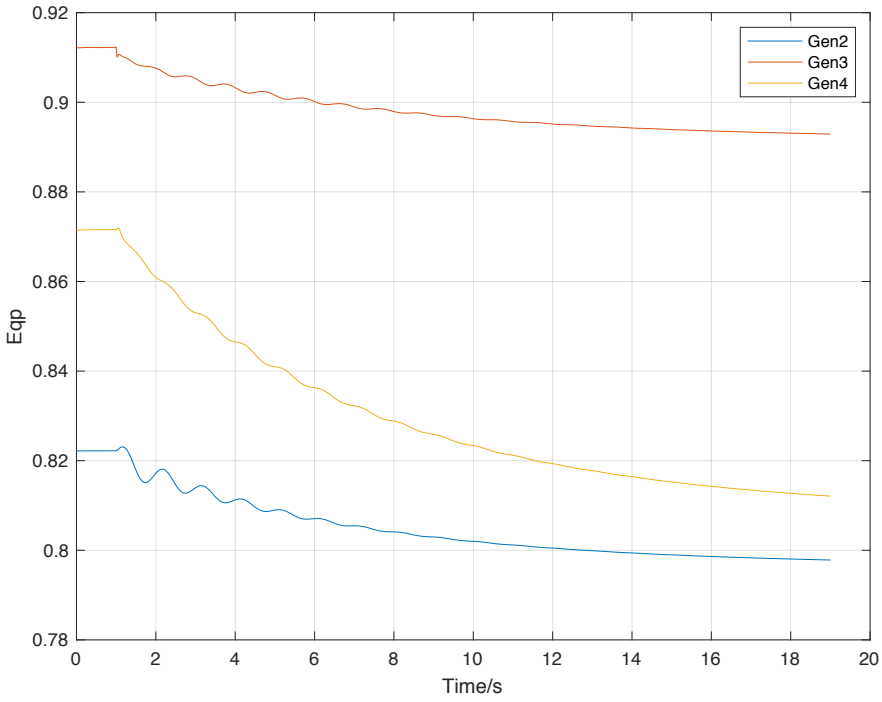
In this analysis, 'Euler method' is used for numerical integration. For type 1 model, since my Newton-Raphson power flow code doesn't perform well for iteration, so I use 'fsolve' command instead. For type1 model, Scripts

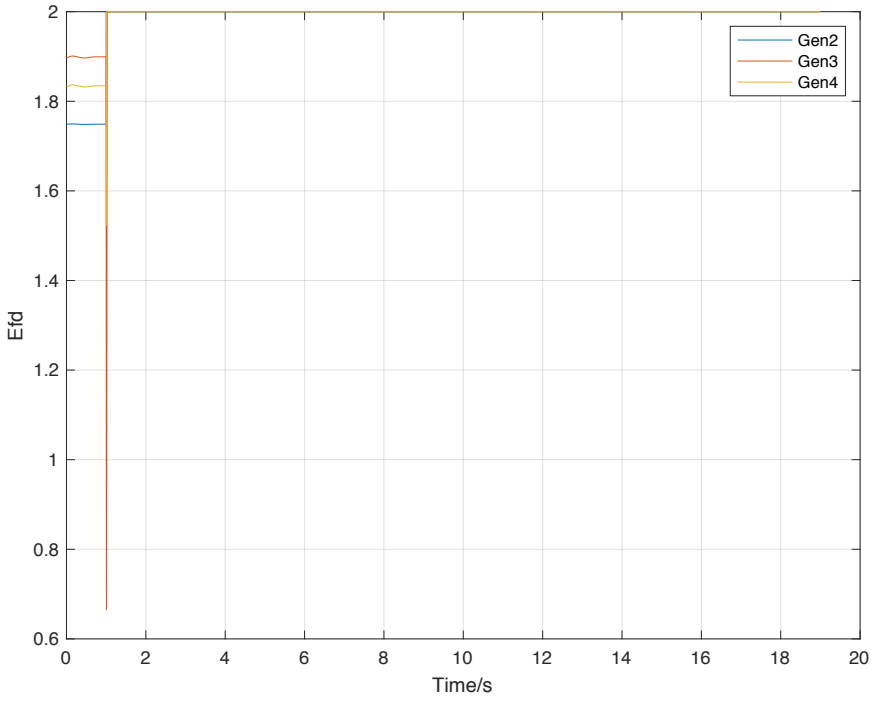
1.Type 1 model
1.1 Responses when tc=3 cycles
When tc=3 cycles, Kundur system is stable, dynamic responses are as shown below:

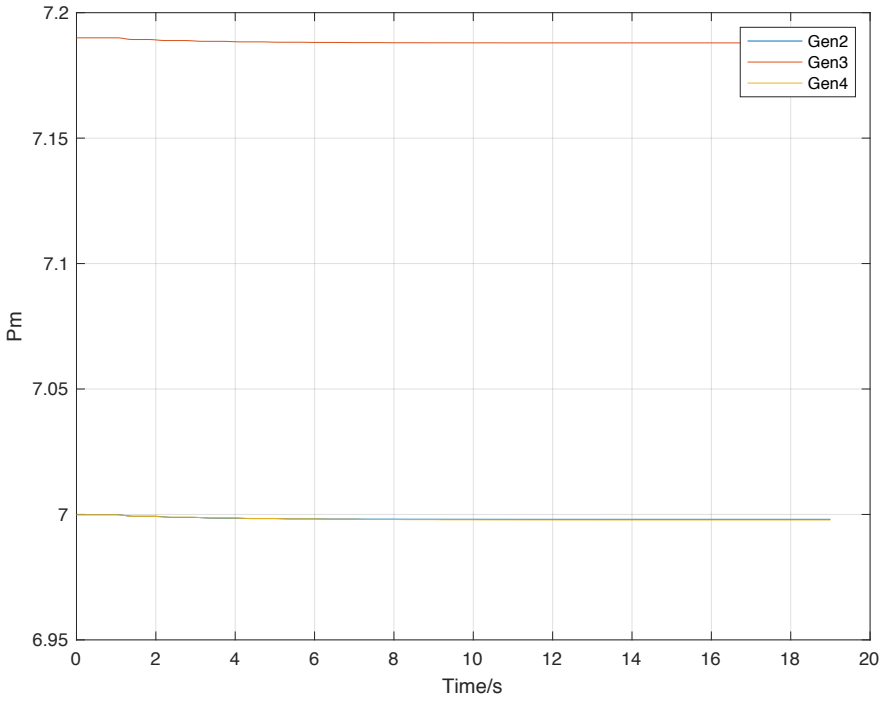



Gen2
Gen3
Gen4
1.002
1.0015
1.001
1.0005
1
0.9995
0.999
ω
0
2
4
6
8
10
12
14
16
18
20
Time/s


Gen2
Gen3
Gen4
0.54
0.52
0.5
0.48
0.46
0.44
0.42
Edp
0
2
4
6
8
10
12
14
16
18
20
Time/s


Gen2
Gen3
Gen4
Eqp
Time/s
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0.78
0
2
4
6
8
10
12
14
16
18
20


Gen2
Gen3
Gen4
Efd
Time/s
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0
2
4
6
8
10
12
14
16
18
20



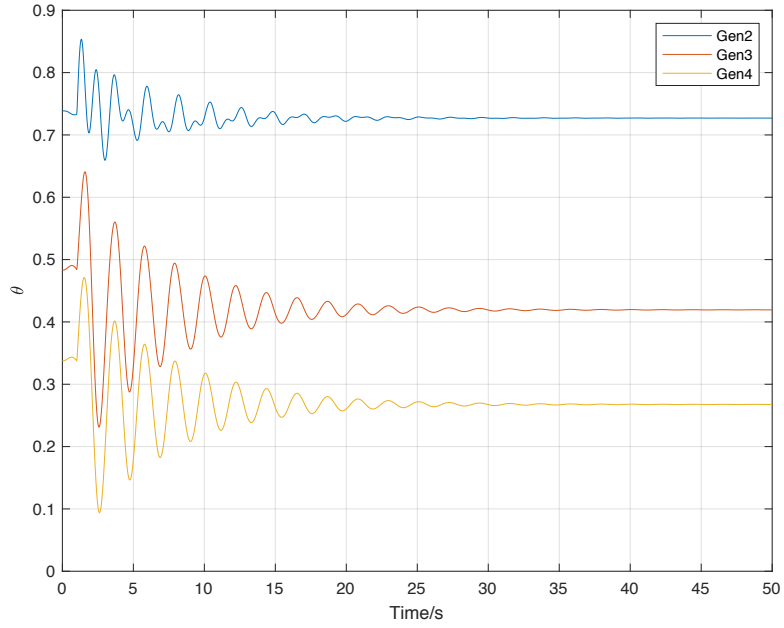
1.2 Responses for Critical Clearing Time

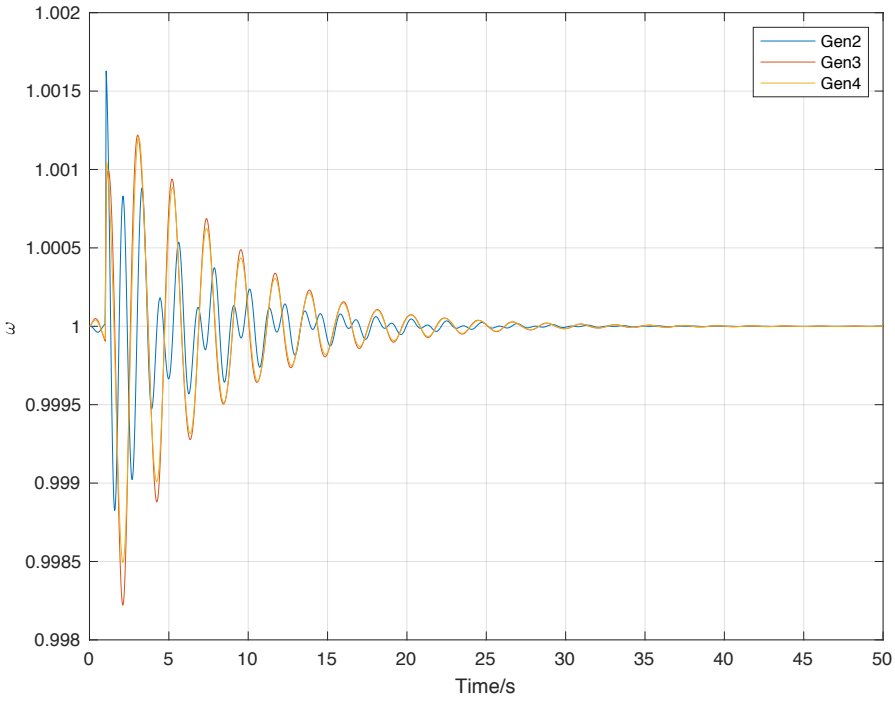
Unfortunately, I couldn't find the critical clearing time for type 1 model.

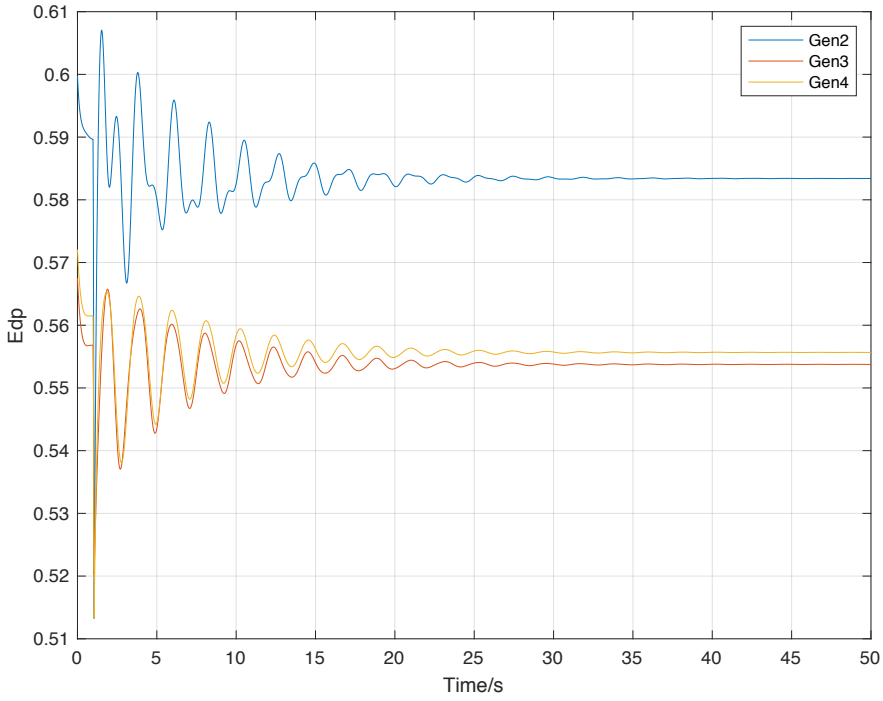
2.Type 2 model

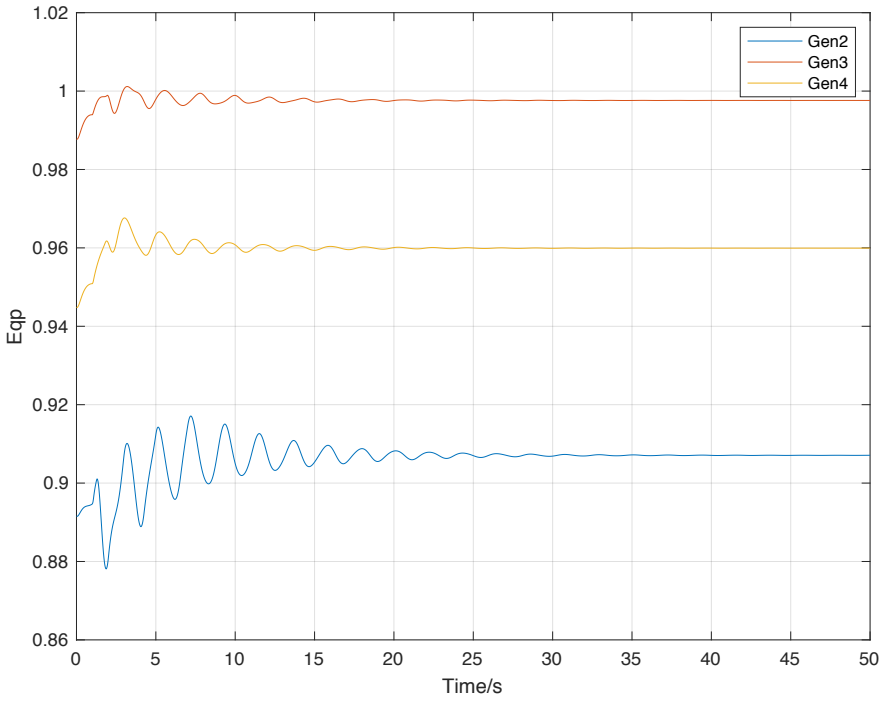
2.1 Responses when tc=3 cycles

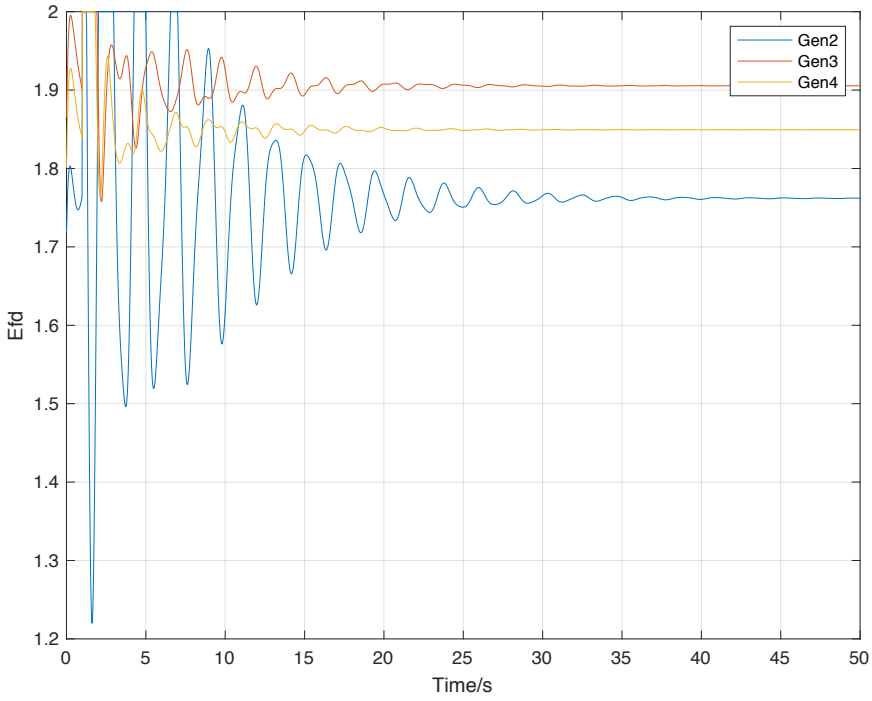
For tc=3 cycles, Kundur system is also stable, dynamic responses for type 2 model are as shown below:

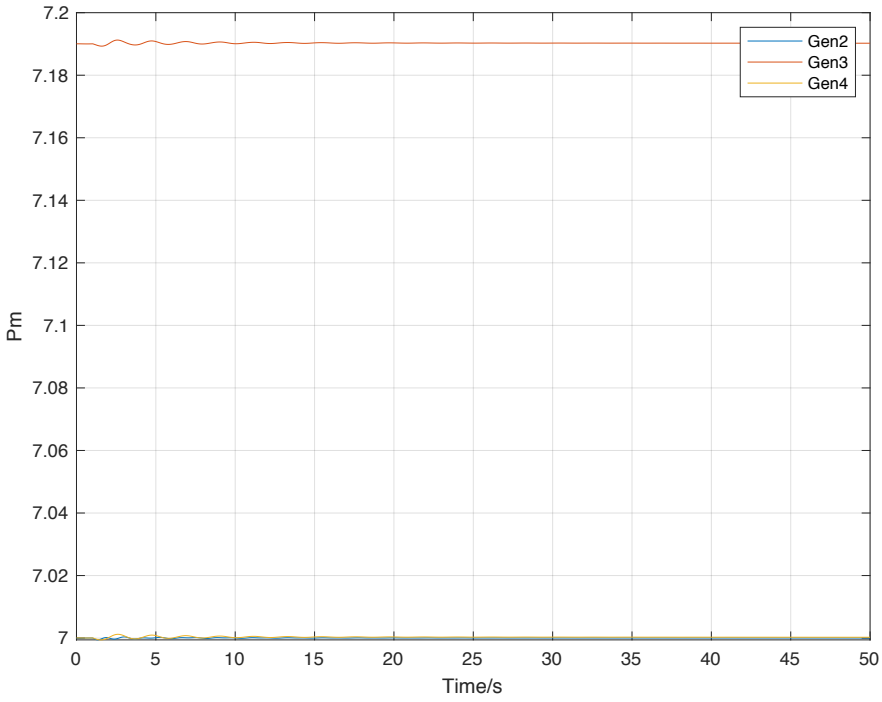



Gen2
Gen3
Gen4
1.002
1.0015
1.001
1.0005
1
0.9995
0.999
0.9985
0.998
ω
0
5
10
15
20
25
30
35
40
45
50
Time/s


Gen2
Gen3
Gen4
0.61
0.6
0.59
0.58
0.57
0.56
0.55
0.54
0.53
0.52
0.51
Edp
0
5
10
15
20
25
30
35
40
45
50
Time/s

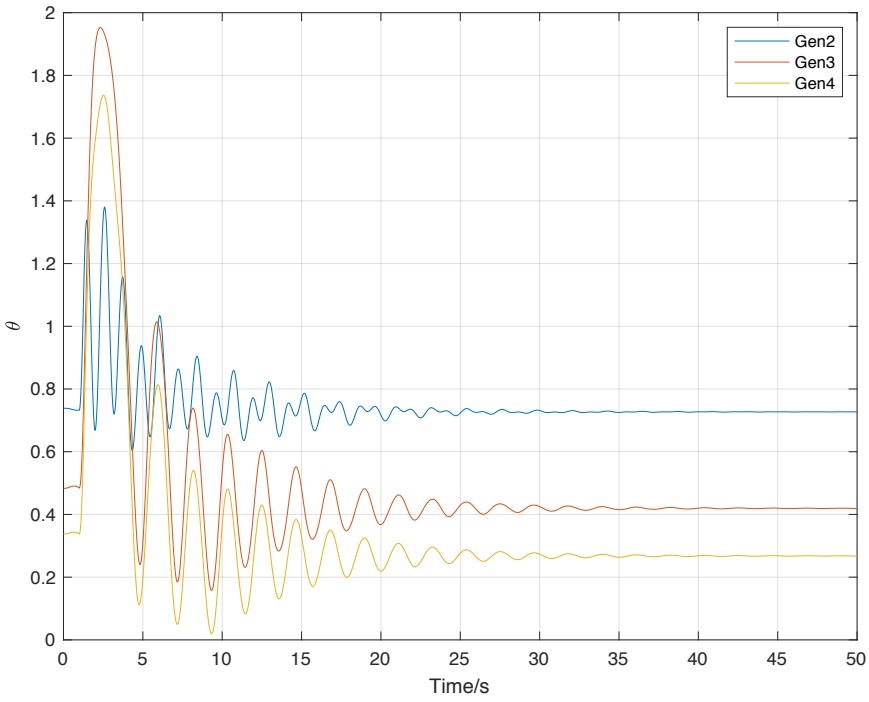

Gen2
Gen3
Gen4
Eqp
Time/s
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0
5
10
15
20
25
30
35
40
45
50

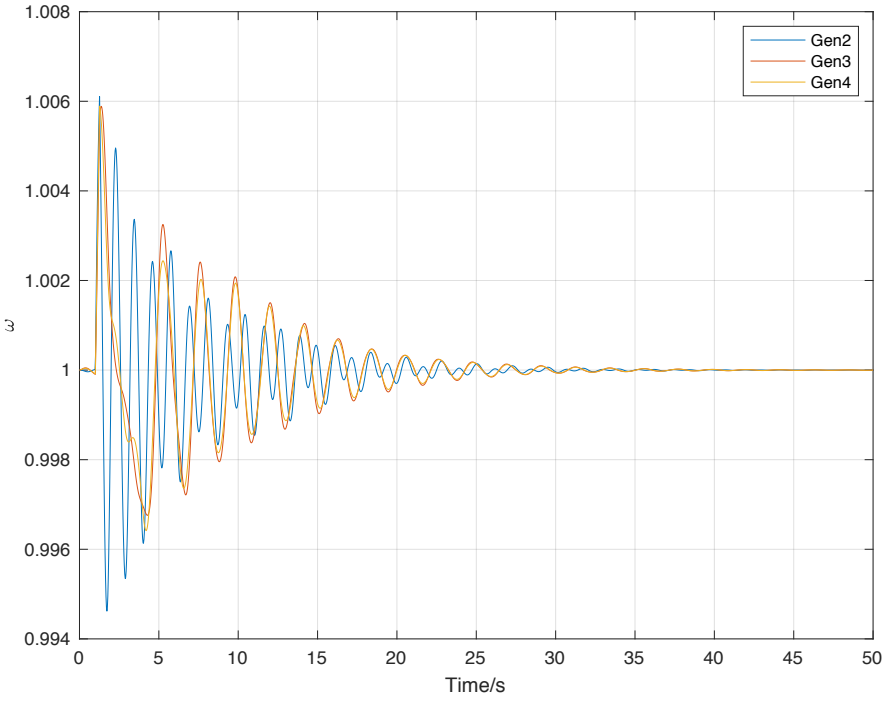

Gen2
Gen3
Gen4
Efd
Time/s
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
0
5
10
15
20
25
30
35
40
45
50

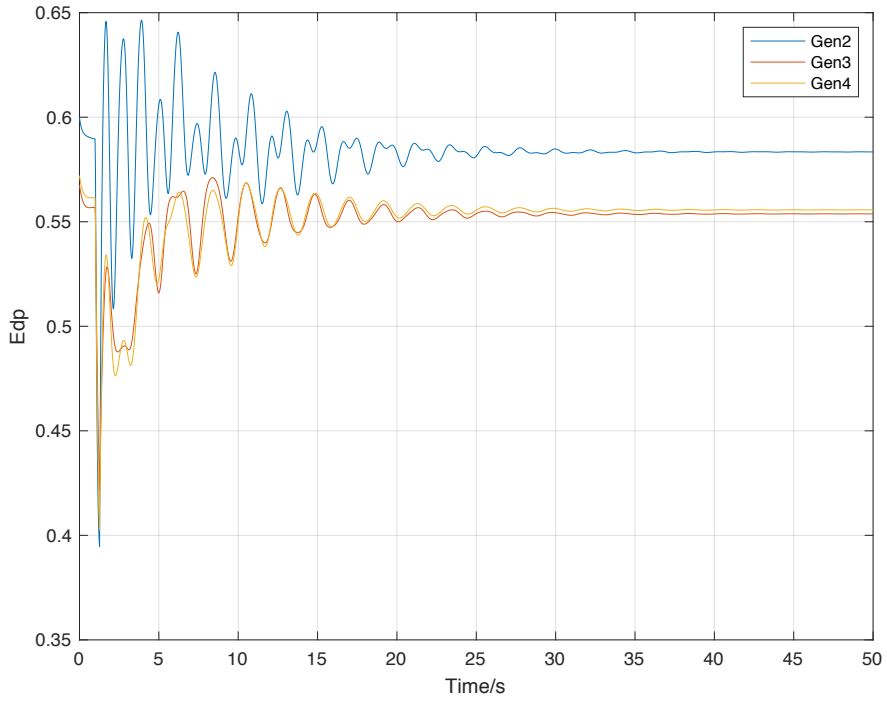


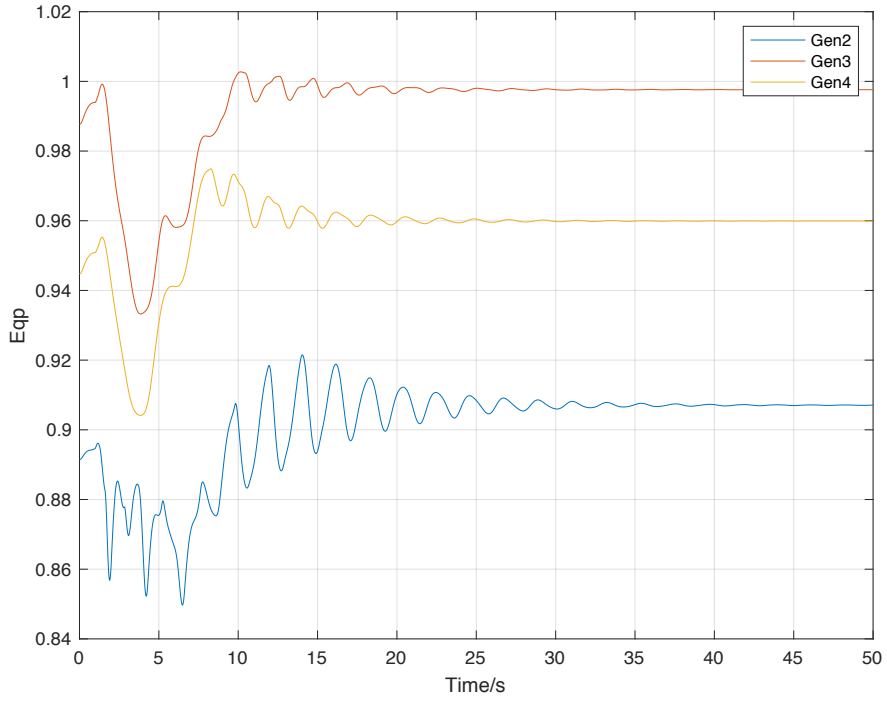
2.2 Responses for Critical Clearing Time
Critical clearing time for type 2 model is 16 cycles.

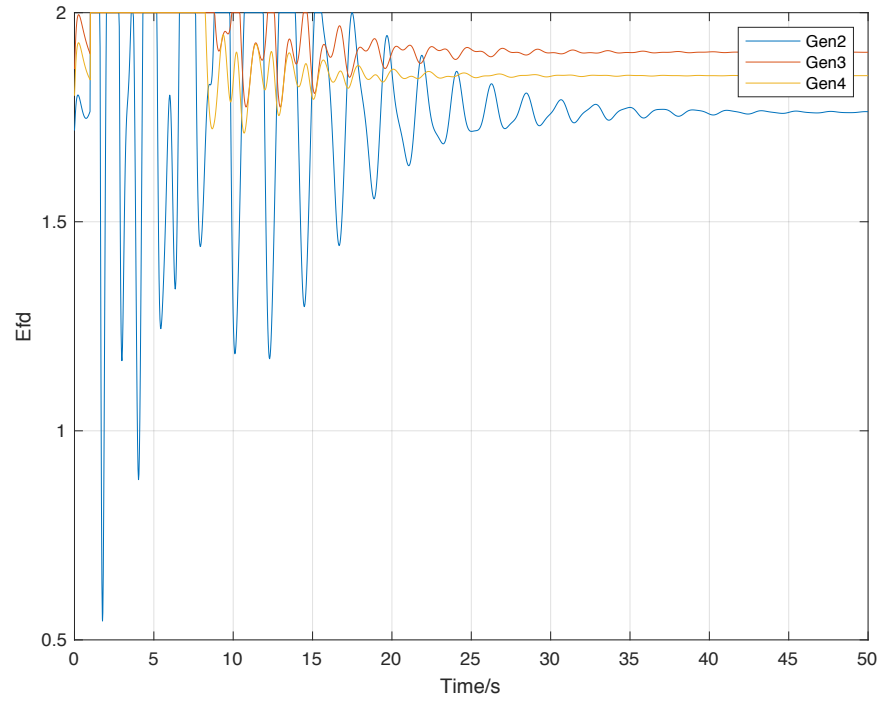
Whentc=16 cycles:

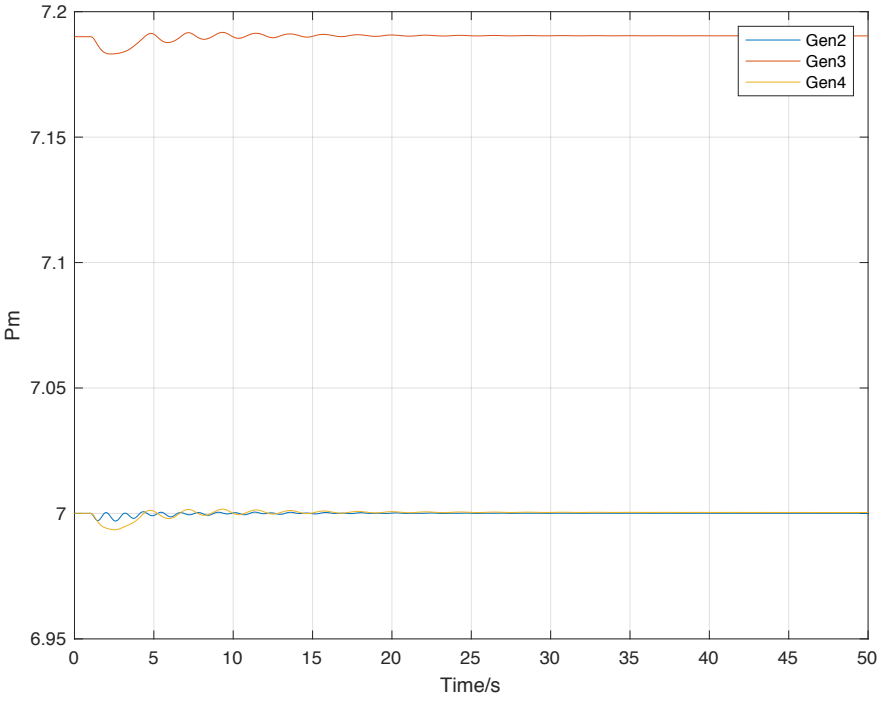

Gen2
Gen3
Gen4
θ
Time/s
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5
10
15
20
25
30
35
40
45
50


Gen2
Gen3
Gen4
ω
Time/s
0.994
0.996
0.998
1
1.002
1.004
1.006
1.008
0
5
10
15
20
25
30
35
40
45
50

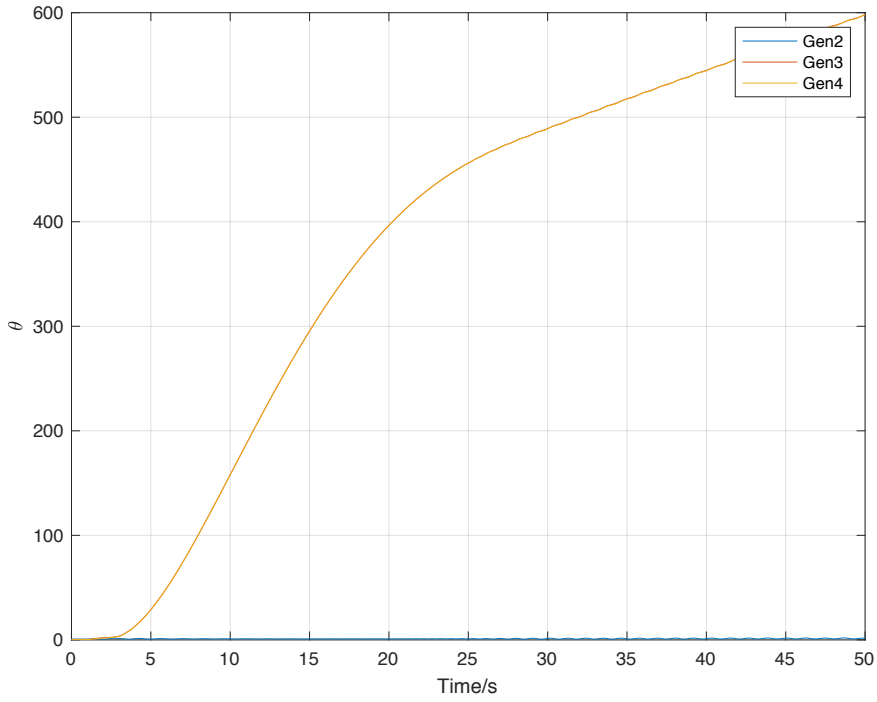

Gen2
Gen3
Gen4
Edp
Time/s
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0
5
10
15
20
25
30
35
40
45
50

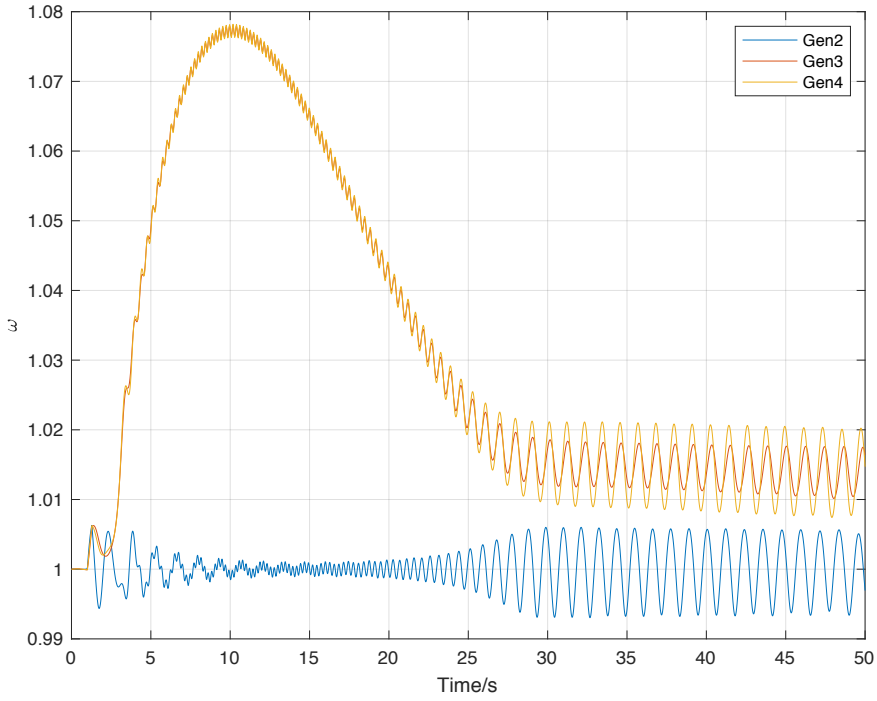

Gen2
Gen3
Gen4
Eqp
Time/s
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0
5
10
15
20
25
30
35
40
45
50

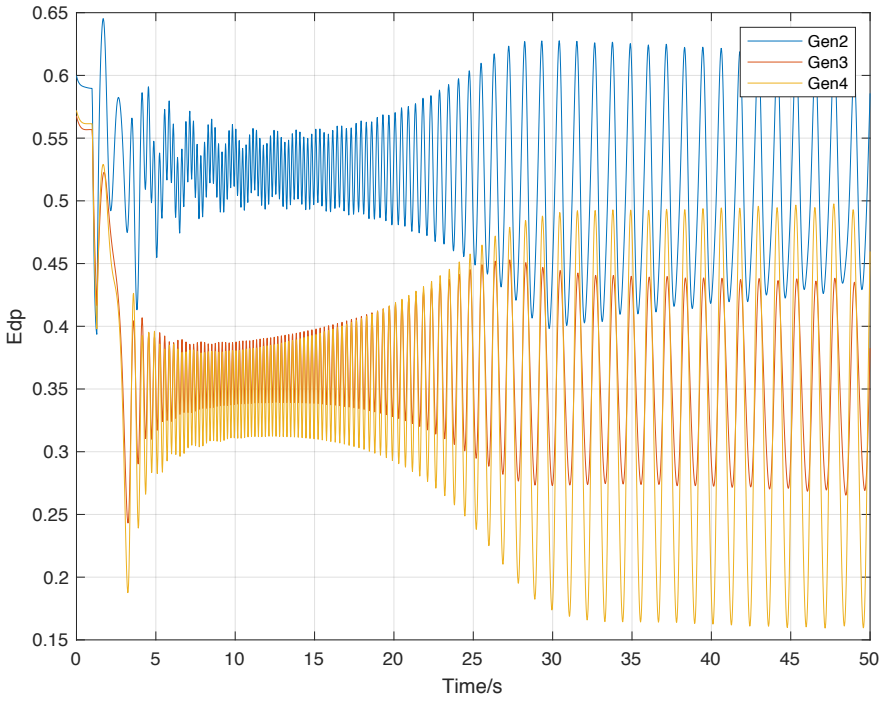


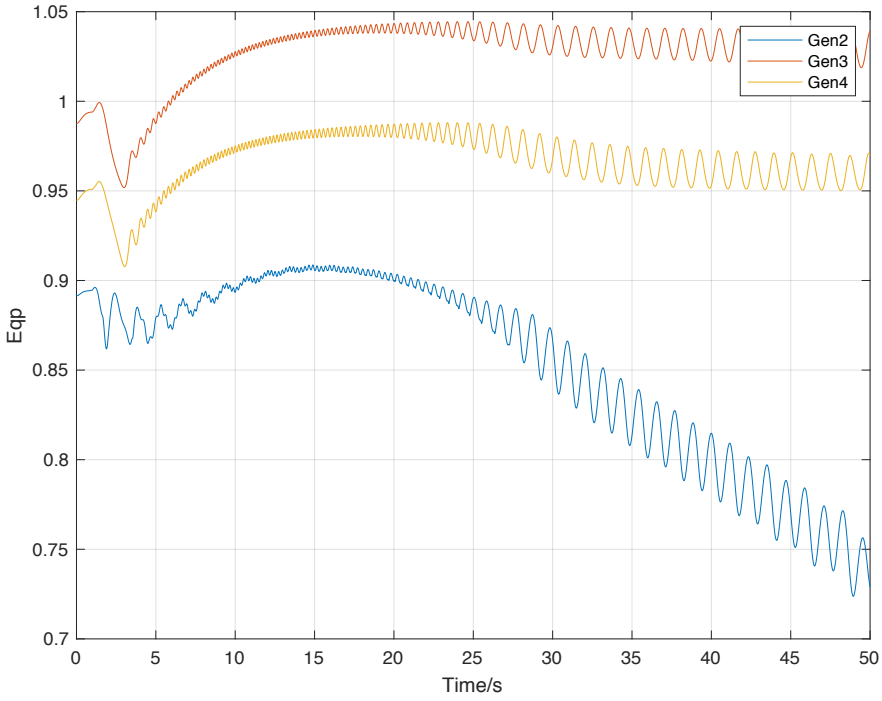


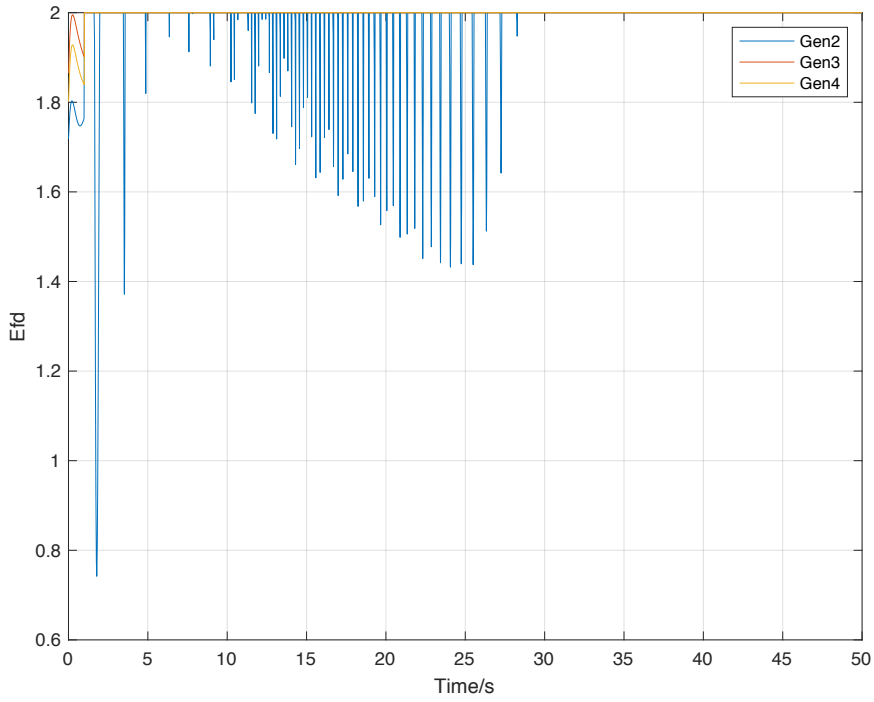
When tc=17 cycles, responses are as shown below:

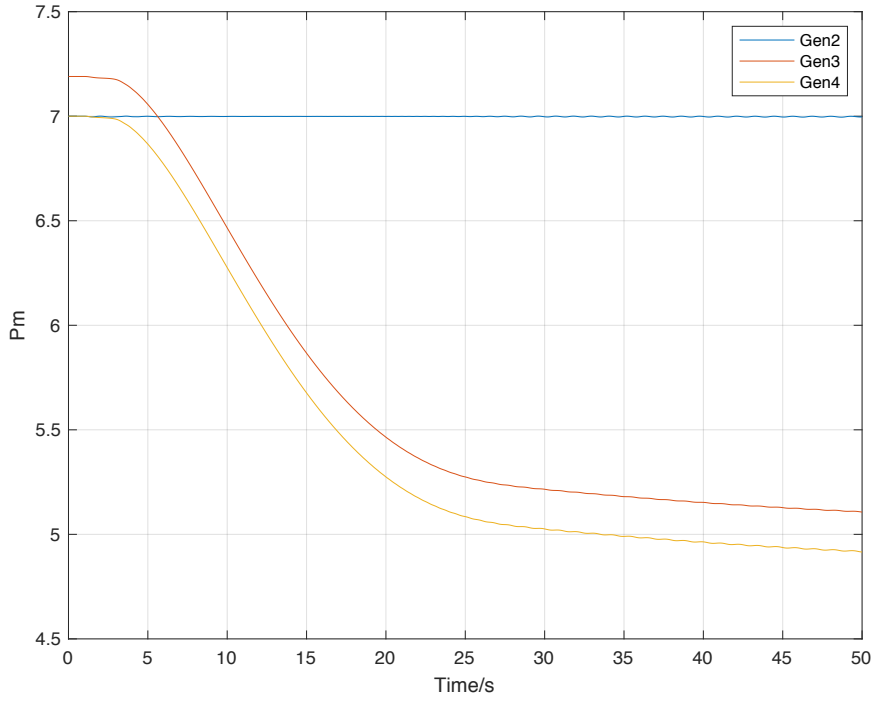

Gen2
Gen3
Gen4
θ
Time/s


Gen2
Gen3
Gen4
ω
Time/s


Gen2
Gen3
Gen4
Edp
Time/s
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0
5
10
15
20
25
30
35
40
45
50

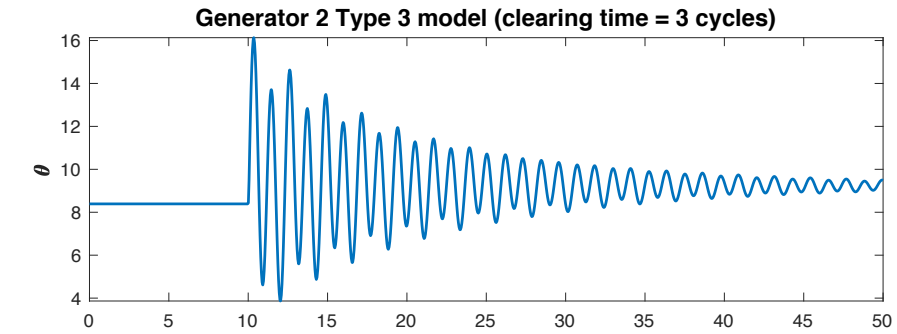

Gen2
Gen3
Gen4
Eqp
Time/s
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0
5
10
15
20
25
30
35
40
45
50

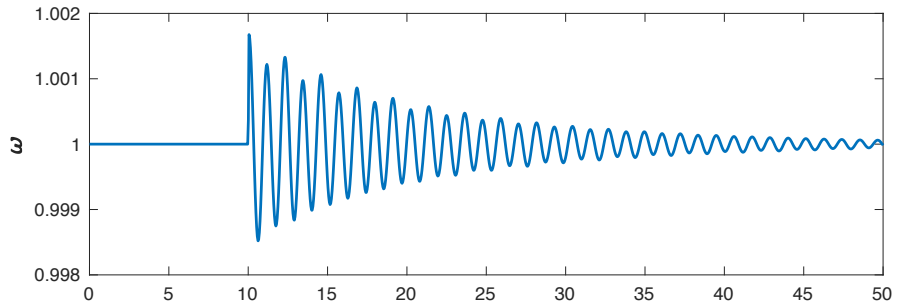


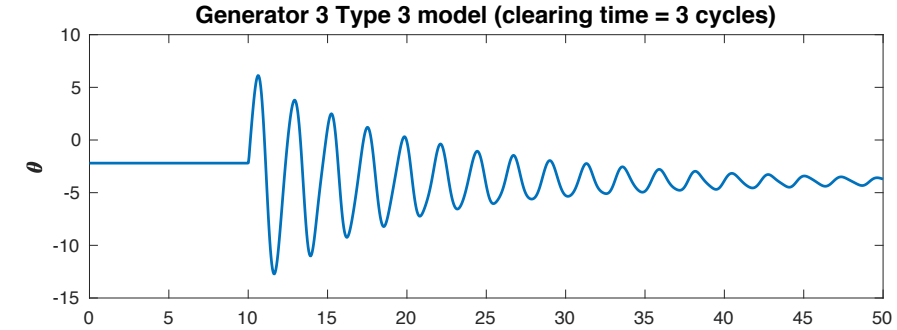


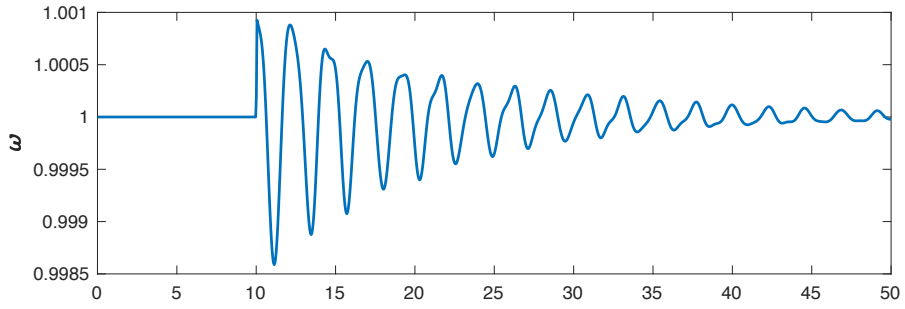
3.Type 3 model

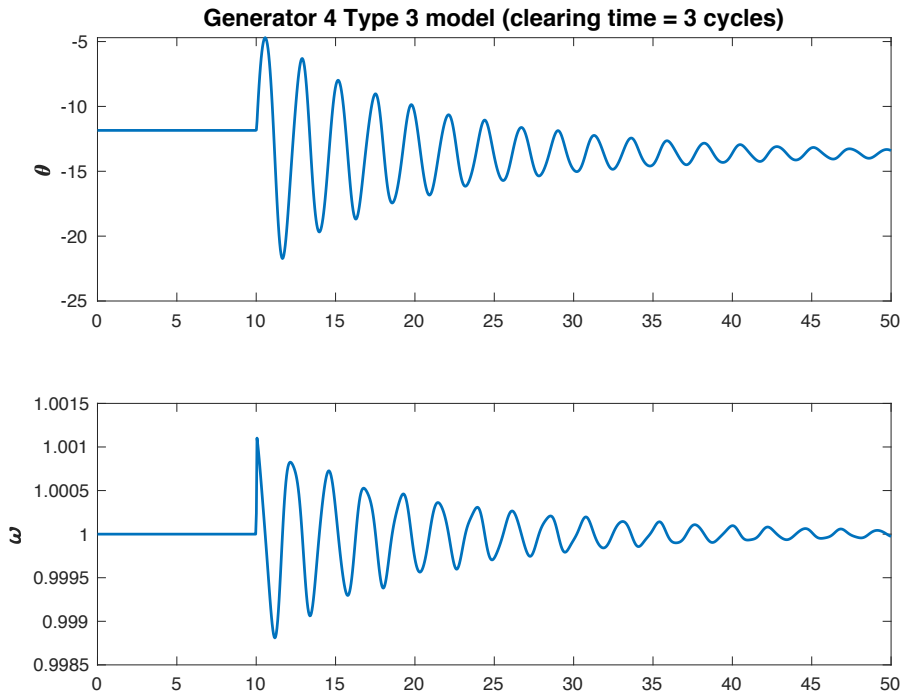
3.1 Responses when tc=3 cycles


Generator 2 Type 3 model (clearing time = 3 cycles)
θ
16
14
12
10
8
6
4
0
5
10
15
20
25
30
35
40
45
50

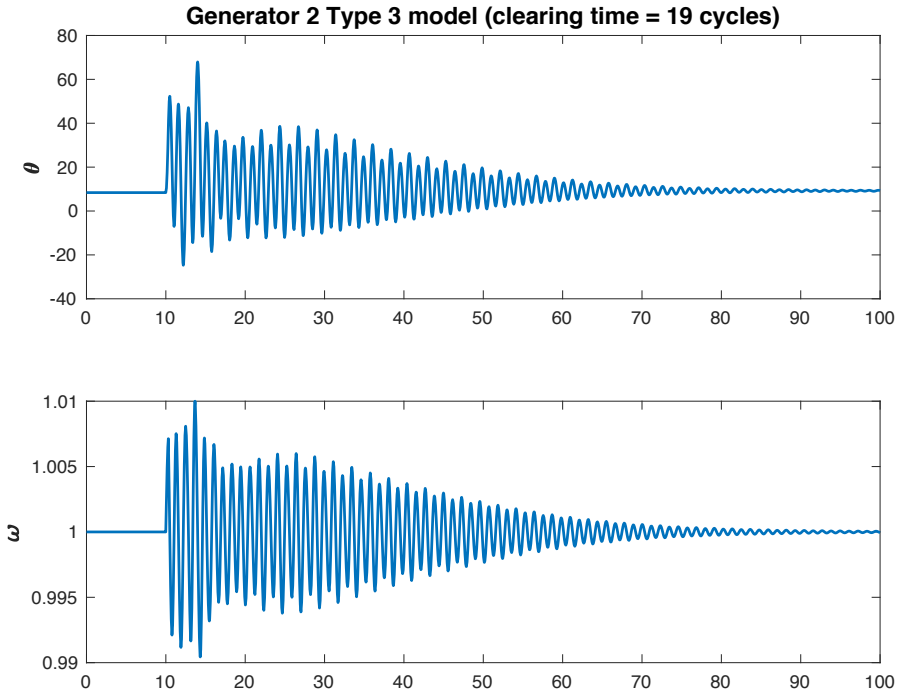

ω
1.002
1.001
1
0.999
0.998
0
5
10
15
20
25
30
35
40
45
50

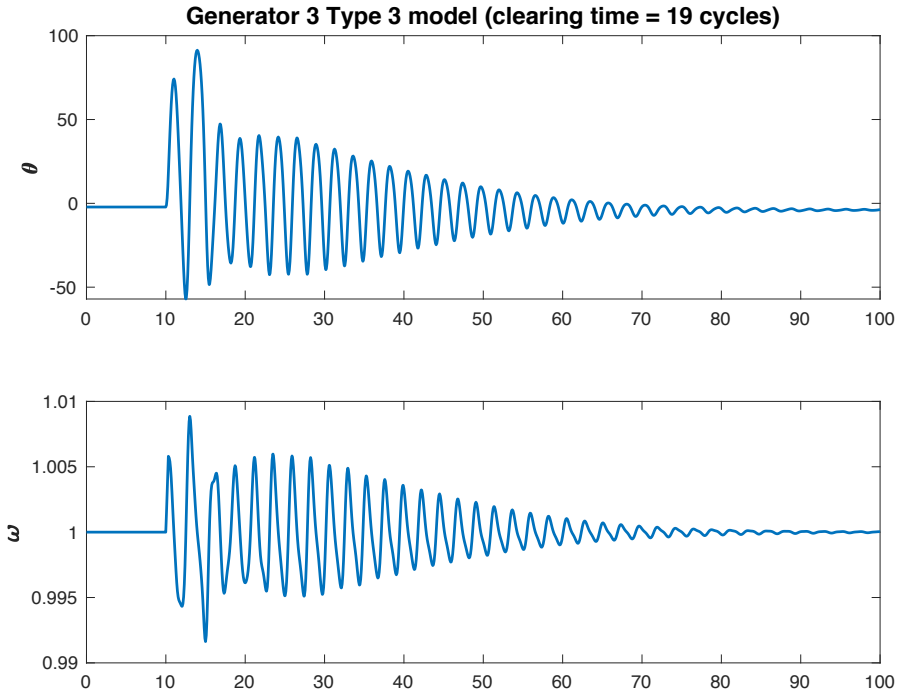

Generator 3 Type 3 model (clearing time = 3 cycles)
θ
10
5
0
-5
-10
-15
0
5
10
15
20
25
30
35
40
45
50

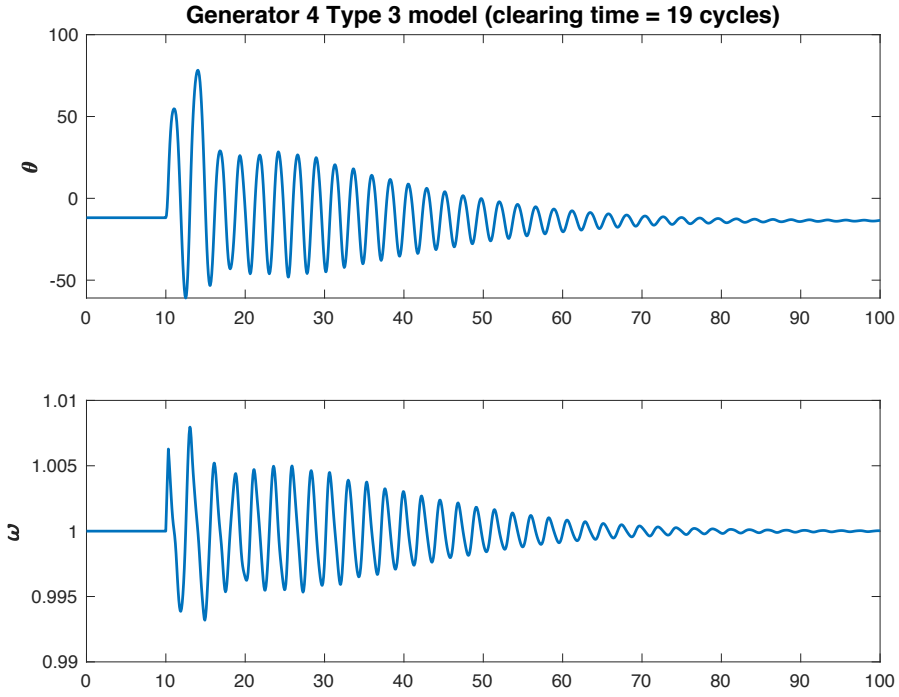

ω
1.001
1.0005
1
0.9995
0.999
0.9985
0
5
10
15
20
25
30
35
40
45
50



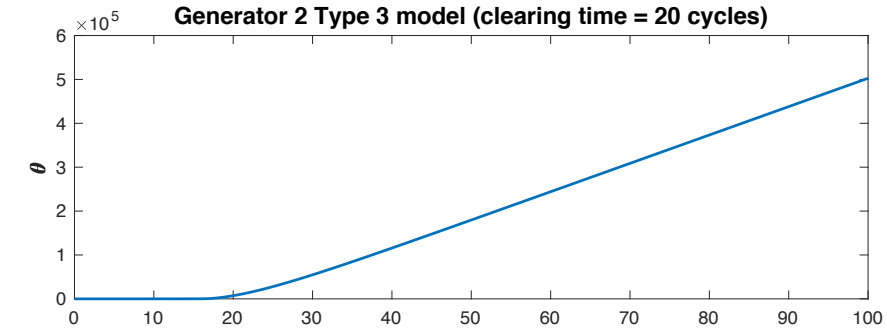
3.2 Responses for Critical Clearing Time
Critical clearing time for type 3 model is 20 cycles.
When tc=19 cycles:

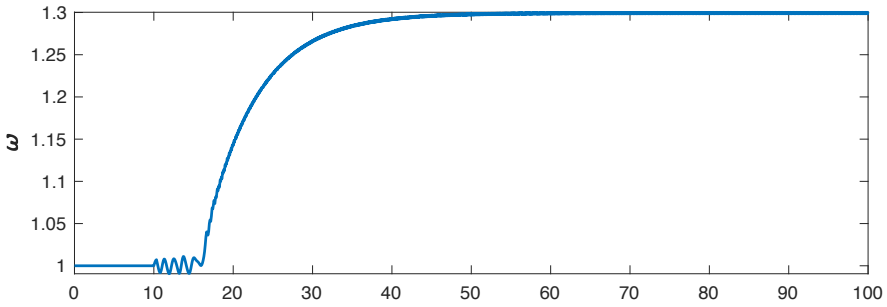


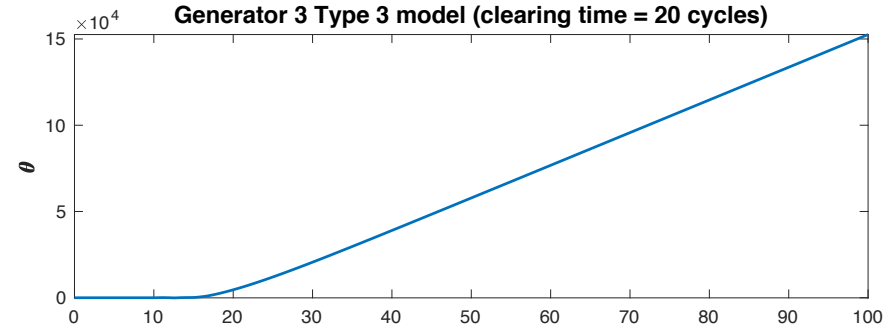

Generator 3 Type 3 model (clearing time = 19 cycles)
θ
100
50
0
-50
0
10
20
30
40
50
60
70
80
90
100
ω
1.01
1.005
1
0.995
0.99
0
10
20
30
40
50
60
70
80
90
100

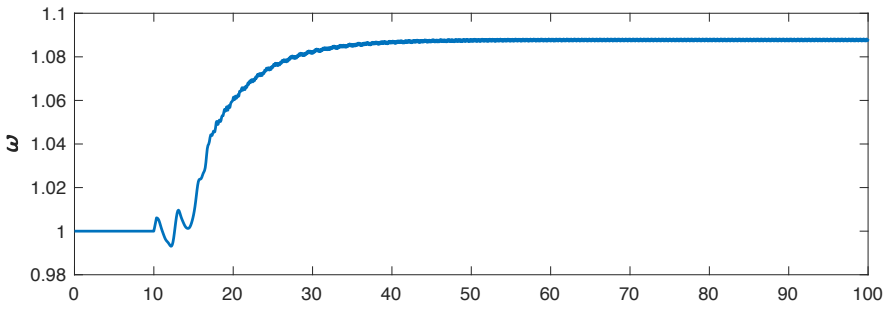

Generator 4 Type 3 model (clearing time = 19 cycles)
θ
100
50
0
-50
0
10
20
30
40
50
60
70
80
90
100
ω
1.01
1.005
1
0.995
0.99
0
10
20
30
40
50
60
70
80
90
100

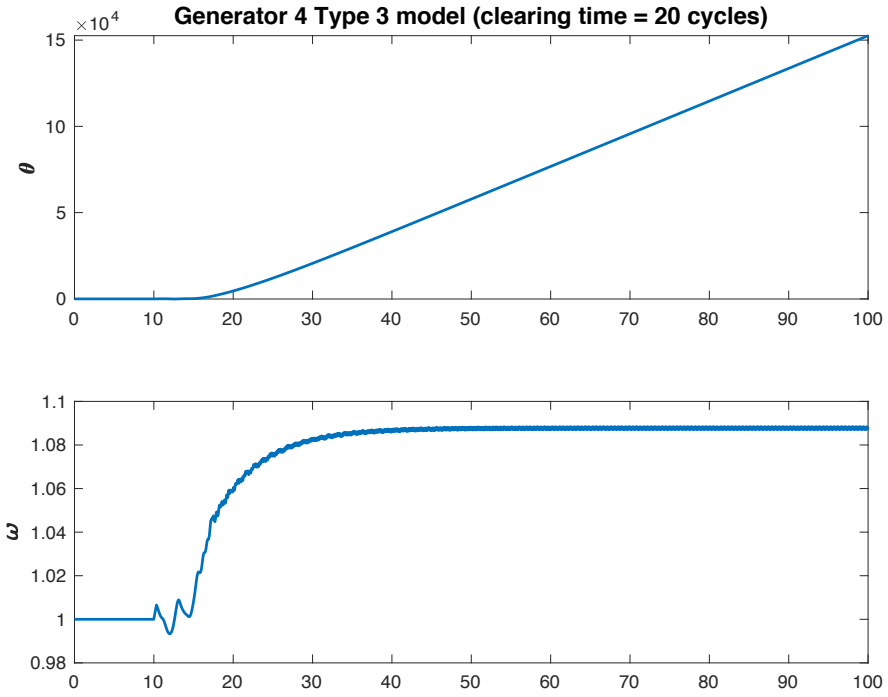
When tc=20 cycles,











Appendix

1 Main script for type-1 model

```
%% homework 6
%generator parameters, changing rating from 900MVA to 100MVA
%p---prime; pp---double prime
clc
clear all
format shortEng
format compact
%% Type2 model fault

fault_time =2;     %%t=t+1    %% This is the time when the fault occurs
clearing_time = 3/60;         %% This is the time of clearance after the fault
has occurred
endtime = 51;     %% t=t+1
h = 1/1000;    %% Step size for simulation


X_d(2:4,1)=1.8*100/900;
X_q(2:4,1)=1.7*100/900;
X_l(2:4,1)=0.2*100/900;
X_dp(2:4,1)=0.3*100/900;
X_qp(2:4,1)=0.55*100/900;
X_dpp(2:4,1)=0.25*100/900;
X_qpp(2:4,1)=0.25*100/900;
R_a(2:4,1)=0;
T_d0p(2:4,1)=8.0;
T_q0p(2:4,1)=0.4;
T_d0pp(2:4,1)=0.03;
T_q0pp(2:4,1)=0.05;
H(1)=6.5*900/100;
```

```
H(2)=6.5*900/100;
H(3)=6.175*900/100;
H(4)=6.175*900/100;
K_D(2:4,1)=2*900/100;

X=(X_d+X_q)/2;
X_p=(X_dp+X_qp)/2;
% for type2
X_dp=X_p;
X_qp=X_p;
ws=2*pi*60;
no_of_states = 6;
%% Exciter parameters
KA=50;
TA=0.01;
VRmin=-4;
VRmax=4;
Efdmin=0;
Efdmax=2.0;

%% Governer parameters
Tsg=100;
Ksg=1;
Psgmin=0;
Psgmax=1*9;
R=0.0056; %convert to Base =100MVA
%% read grid data from file
file_name='b_kundur_system.txt';
[S_Base,No_of_Buses,No_of_Lines,Bus_data,Line_data]=read_data(file_name);
[PQ,nPQ,PV,nPV,Y_mat,V_mag,V_Delta,P_gen_cal,Q_gen_cal, V_result]=
NR_power_flow(S_Base,No_of_Buses,No_of_Lines,Bus_data,Line_data);

%% revise y matrix, and form y_gen
file_name_2='b_kundur_system_extended.txt';
[S_Base_2,No_of_Buses_2,No_of_Lines_2,Bus_data_2,Line_data_2]=read_data(file_
name_2);
[Y_mat_ex,Theta_ex,Y_mag_ex,B_ex,G_ex]=y_bus(Bus_data_2,Line_data_2,No_of_Bus
es_2,No_of_Lines_2);
[Y_gen,Y_gen_mag,Y_gen_angle]=Ygen(Y_mat_ex,4,10);

%% solving for equilibrium point at t=0
S=complex(P_gen_cal, Q_gen_cal);
I=conj(S./(V_mag.*cos(V_Delta)+1i.*V_mag.*sin(V_Delta)));
I_mag=abs(I);
I_angle=angle(I);
E_p=zeros(4,1);
for i=1:4
E_p(i)=complex(V_mag(i)*cos(V_Delta(i)),V_mag(i).*sin(V_Delta(i)))+I(i).*(R_a
(i)+1i.*X_p(i));
end
E_p_mag=abs(E_p); %E'
E_p_angle=angle(E_p); %gama

for genbus=1:4 %generator buses, including slack bus
     x0=[0;1;1.06;0;1;1;1;1;1;1;1;1]; %
    [solution,~,exitflag] = fsolve(@(x)
type2_equilibrium_points(x,genbus,ws,K_D,X,X_p,X,X_p,KA,V_mag,Y_gen_mag,Y_gen
```

```
_angle,E_p_mag,E_p_angle,R),x0,optimset('algorithm','levenberg-
marquardt','display','off'));
    theta_0(genbus,1)=solution(1);
    omega_0(genbus,1)=solution(2);
    E_qp0(genbus,1)=solution(3);
    E_dp0(genbus,1)=solution(4);
    E_fd0(genbus,1)=solution(7);
    Pm_0(genbus,1)=solution(8);
    V_ref(genbus,1)=solution(9);
    Pc_0(genbus,1)=solution(10);
    Pe_0(genbus,1)=solution(11);
    Id_0(genbus,1)=solution(5);
    Iq_0(genbus,1)=solution(6);

end

%% Transient stability analysis
%% prefault
iter=1;
for iteration=1:h:fault_time
   [theta_0,omega_0,E_dp0, E_qp0,E_fd0, Pm_0,V_mag]=type2_euler(Pm_0,
Pc_0,PV, nPV,H,Y_gen,Y_gen_mag,Y_gen_angle,V_mag,theta_0,omega_0,ws,K_D,h,...
       E_qp0, E_dp0, E_fd0, V_ref, X_d, X_q, X_dp, X_qp,X_p,
T_d0p,T_q0p,KA,TA,Tsg,Ksg,R, VRmax,VRmin,Efdmax,Efdmin,Psgmax,Psgmin);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=omega_0;
    Edp(:,iter)= E_dp0;
    Eqp(:,iter)= E_qp0;
    Efd(:,iter)= E_fd0;
    Pm(:,iter)= Pm_0;
    iter=iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end
%     plot(time,rad2deg(theta(2,:)),'linewidth',1.5)
%% onfault
% revise y matrix, and form y_gen
file_name_3='onfault_b_kundur_system_extended.txt';
[S_Base_3,No_of_Buses_3,No_of_Lines_3,Bus_data_3,Line_data_3]=read_data(file_
name_3);
[Y_mat_ex_f,Theta_ex_f,Y_mag_ex_f,B_ex_f,G_ex_f]=y_bus(Bus_data_3,Line_data_3
,No_of_Buses_3,No_of_Lines_3);
[Y_gen_f,Y_gen_mag_f,Y_gen_angle_f]=Ygen(Y_mat_ex_f,4,11);

for iteration=fault_time:h:(fault_time+clearing_time)
     [theta_0,omega_0,E_dp0, E_qp0,E_fd0, Pm_0,V_mag]=type2_euler(Pm_0,
Pc_0,PV,
nPV,H,Y_gen_f,Y_gen_mag_f,Y_gen_angle_f,V_mag,theta_0,omega_0,ws,K_D,h,...
       E_qp0, E_dp0, E_fd0, V_ref, X_d, X_q, X_dp, X_qp,X_p,
T_d0p,T_q0p,KA,TA,Tsg,Ksg,R,VRmax,VRmin,Efdmax,Efdmin,Psgmax,Psgmin);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=omega_0;
    Edp(:,iter)= E_dp0;
    Eqp(:,iter)= E_qp0;
    Efd(:,iter)= E_fd0;
    Pm(:,iter)= Pm_0;
iter = iter+1;
```

```
end
iter=iter-1; %% To delete the extra time step added at the end

%% post fault analysis
% revise y matrix, and form y_gen
file_name_4='postfault_b_kundur_system_extended.txt';
[S_Base_4,No_of_Buses_4,No_of_Lines_4,Bus_data_4,Line_data_4]=read_data(file_
name_4);
[Y_mat_ex_pf,Theta_ex_pf,Y_mag_ex_pf,B_ex_pf,G_ex_pf]=y_bus(Bus_data_4,Line_d
ata_4,No_of_Buses_4,No_of_Lines_4);
[Y_gen_pf,Y_gen_mag_pf,Y_gen_angle_pf]=Ygen(Y_mat_ex_pf,4,10);

for iteration=(fault_time+clearing_time):h:endtime
   [theta_0,omega_0,E_dp0, E_qp0,E_fd0, Pm_0,V_mag]=type2_euler(Pm_0,
Pc_0,PV,
nPV,H,Y_gen_pf,Y_gen_mag_pf,Y_gen_angle_pf,V_mag,theta_0,omega_0,ws,K_D,h,...
        E_qp0, E_dp0, E_fd0, V_ref, X_d, X_q, X_dp, X_qp,X_p,
T_d0p,T_q0p,KA,TA,Tsg,Ksg,R,VRmax,VRmin,Efdmax,Efdmin,Psgmax,Psgmin);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=omega_0;
    Edp(:,iter)= E_dp0;
    Eqp(:,iter)= E_qp0;
    Efd(:,iter)= E_fd0;
    Pm(:,iter)= Pm_0;
iter = iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end

%% plot graphs

figure(1)
plot(time,theta(2:4,:)); grid on;
ylabel('\theta');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(2)
plot(time,w(2:4,:)); grid on;
ylabel('\omega');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(3)
plot(time,Edp(2:4,:)); grid on;
ylabel('Edp');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(4)
plot(time,Eqp(2:4,:)); grid on;
ylabel('Eqp');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(5)
plot(time,Efd(2:4,:)); grid on;
```

```
ylabel('Efd');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(6)
plot(time,Pm(2:4,:)); grid on;
ylabel('Pm');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )
```

2 Main script for type-2 model

```
%% homework 6
%generator parameters, changing rating from 900MVA to 100MVA
%p---prime; pp---double prime
clc
clear all
format shortEng
format compact
%% Type2 model fault

fault_time =2;    %%t=t+1   %% This is the time when the fault occurs
clearing_time = 3/60;        %% This is the time of clearance after the fault
has occurred
endtime = 51;    %% t=t+1
h = 1/1000;   %% Step size for simulation


X_d(2:4,1)=1.8*100/900;
X_q(2:4,1)=1.7*100/900;
X_l(2:4,1)=0.2*100/900;
X_dp(2:4,1)=0.3*100/900;
X_qp(2:4,1)=0.55*100/900;
X_dpp(2:4,1)=0.25*100/900;
X_qpp(2:4,1)=0.25*100/900;
R_a(2:4,1)=0;
T_d0p(2:4,1)=8.0;
T_q0p(2:4,1)=0.4;
T_d0pp(2:4,1)=0.03;
T_q0pp(2:4,1)=0.05;
H(1)=6.5*900/100;
H(2)=6.5*900/100;
H(3)=6.175*900/100;
H(4)=6.175*900/100;
K_D(2:4,1)=2*900/100;

X=(X_d+X_q)/2;
X_p=(X_dp+X_qp)/2;
% for type2
X_dp=X_p;
X_qp=X_p;
ws=2*pi*60;
no_of_states = 6;
%% Exciter parameters
KA=50;
TA=0.01;
```

```
VRmin=-4;
VRmax=4;
Efdmin=0;
Efdmax=2.0;

%% Governer parameters
Tsg=100;
Ksg=1;
Psgmin=0;
Psgmax=1*9;
R=0.0056; %convert to Base =100MVA
%% read grid data from file
file_name='b_kundur_system.txt';
[S_Base,No_of_Buses,No_of_Lines,Bus_data,Line_data]=read_data(file_name);
[PQ,nPQ,PV,nPV,Y_mat,V_mag,V_Delta,P_gen_cal,Q_gen_cal, V_result]=
NR_power_flow(S_Base,No_of_Buses,No_of_Lines,Bus_data,Line_data);

%% revise y matrix, and form y_gen
file_name_2='b_kundur_system_extended.txt';
[S_Base_2,No_of_Buses_2,No_of_Lines_2,Bus_data_2,Line_data_2]=read_data(file_
name_2);
[Y_mat_ex,Theta_ex,Y_mag_ex,B_ex,G_ex]=y_bus(Bus_data_2,Line_data_2,No_of_Bus
es_2,No_of_Lines_2);
[Y_gen,Y_gen_mag,Y_gen_angle]=Ygen(Y_mat_ex,4,10);

%% solving for equilibrium point at t=0
S=complex(P_gen_cal, Q_gen_cal);
I=conj(S./(V_mag.*cos(V_Delta)+1i.*V_mag.*sin(V_Delta)));
I_mag=abs(I);
I_angle=angle(I);
E_p=zeros(4,1);
for i=1:4
E_p(i)=complex(V_mag(i)*cos(V_Delta(i)),V_mag(i).*sin(V_Delta(i)))+I(i).*(R_a
(i)+1i.*X_p(i));
end
E_p_mag=abs(E_p); %E'
E_p_angle=angle(E_p); %gama

for genbus=1:4 %generator buses, including slack bus
     x0=[0;1;1.06;0;1;1;1;1;1;1;1]; %
    [solution,~,exitflag] = fsolve(@(x)
type2_equilibrium_points(x,genbus,ws,K_D,X,X_p,X,X_p,KA,V_mag,Y_gen_mag,Y_gen
_angle,E_p_mag,E_p_angle,R),x0,optimset('algorithm','levenberg-
marquardt','display','off'));
    theta_0(genbus,1)=solution(1);
    omega_0(genbus,1)=solution(2);
    E_qp0(genbus,1)=solution(3);
    E_dp0(genbus,1)=solution(4);
    E_fd0(genbus,1)=solution(7);
    Pm_0(genbus,1)=solution(8);
    V_ref(genbus,1)=solution(9);
    Pc_0(genbus,1)=solution(10);
    Pe_0(genbus,1)=solution(11);
    Id_0(genbus,1)=solution(5);
    Iq_0(genbus,1)=solution(6);

end
```

```
%% Transient stability analysis
%% prefault
iter=1;
for iteration=1:h:fault_time
   [theta_0,omega_0,E_dp0, E_qp0,E_fd0, Pm_0,V_mag]=type2_euler(Pm_0,
Pc_0,PV, nPV,H,Y_gen,Y_gen_mag,Y_gen_angle,V_mag,theta_0,omega_0,ws,K_D,h,...
        E_qp0, E_dp0, E_fd0, V_ref, X_d, X_q, X_dp, X_qp,X_p,
T_d0p,T_q0p,KA,TA,Tsg,Ksg,R, VRmax,VRmin,Efdmax,Efdmin,Psgmax,Psgmin);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=omega_0;
    Edp(:,iter)= E_dp0;
    Eqp(:,iter)= E_qp0;
    Efd(:,iter)= E_fd0;
    Pm(:,iter)= Pm_0;
    iter=iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end
%     plot(time,rad2deg(theta(2,:)),'linewidth',1.5)
%% onfault
% revise y matrix, and form y_gen
file_name_3='onfault_b_kundur_system_extended.txt';
[S_Base_3,No_of_Buses_3,No_of_Lines_3,Bus_data_3,Line_data_3]=read_data(file_
name_3);
[Y_mat_ex_f,Theta_ex_f,Y_mag_ex_f,B_ex_f,G_ex_f]=y_bus(Bus_data_3,Line_data_3
,No_of_Buses_3,No_of_Lines_3);
[Y_gen_f,Y_gen_mag_f,Y_gen_angle_f]=Ygen(Y_mat_ex_f,4,11);

for iteration=fault_time:h:(fault_time+clearing_time)
     [theta_0,omega_0,E_dp0, E_qp0,E_fd0, Pm_0,V_mag]=type2_euler(Pm_0,
Pc_0,PV,
nPV,H,Y_gen_f,Y_gen_mag_f,Y_gen_angle_f,V_mag,theta_0,omega_0,ws,K_D,h,...
        E_qp0, E_dp0, E_fd0, V_ref, X_d, X_q, X_dp, X_qp,X_p,
T_d0p,T_q0p,KA,TA,Tsg,Ksg,R,VRmax,VRmin,Efdmax,Efdmin,Psgmax,Psgmin);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=omega_0;
    Edp(:,iter)= E_dp0;
    Eqp(:,iter)= E_qp0;
    Efd(:,iter)= E_fd0;
    Pm(:,iter)= Pm_0;
iter = iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end

%% post fault analysis
% revise y matrix, and form y_gen
file_name_4='postfault_b_kundur_system_extended.txt';
[S_Base_4,No_of_Buses_4,No_of_Lines_4,Bus_data_4,Line_data_4]=read_data(file_
name_4);
[Y_mat_ex_pf,Theta_ex_pf,Y_mag_ex_pf,B_ex_pf,G_ex_pf]=y_bus(Bus_data_4,Line_d
ata_4,No_of_Buses_4,No_of_Lines_4);
[Y_gen_pf,Y_gen_mag_pf,Y_gen_angle_pf]=Ygen(Y_mat_ex_pf,4,10);

for iteration=(fault_time+clearing_time):h:endtime
```

```
   [theta_0,omega_0,E_dp0, E_qp0,E_fd0, Pm_0,V_mag]=type2_euler(Pm_0,
Pc_0,PV,
nPV,H,Y_gen_pf,Y_gen_mag_pf,Y_gen_angle_pf,V_mag,theta_0,omega_0,ws,K_D,h,...
        E_qp0, E_dp0, E_fd0, V_ref, X_d, X_q, X_dp, X_qp,X_p,
T_d0p,T_q0p,KA,TA,Tsg,Ksg,R,VRmax,VRmin,Efdmax,Efdmin,Psgmax,Psgmin);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=omega_0;
    Edp(:,iter)= E_dp0;
    Eqp(:,iter)= E_qp0;
    Efd(:,iter)= E_fd0;
    Pm(:,iter)= Pm_0;
iter = iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end

%% plot graphs

figure(1)
plot(time,theta(2:4,:)); grid on;
ylabel('\theta');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(2)
plot(time,w(2:4,:)); grid on;
ylabel('\omega');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(3)
plot(time,Edp(2:4,:)); grid on;
ylabel('Edp');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(4)
plot(time,Eqp(2:4,:)); grid on;
ylabel('Eqp');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(5)
plot(time,Efd(2:4,:)); grid on;
ylabel('Efd');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )

figure(6)
plot(time,Pm(2:4,:)); grid on;
ylabel('Pm');
xlabel('Time/s');
legend('Gen2','Gen3','Gen4' )
```

3 Main script for type-3 model

```
%% homework 7
%generator parameters, changing rating from 900MVA to 100MVA
%p---prime; pp---double prime
clc
clear all
format short
%% Type3 model fault

fault_time = 11;    %%t=t+1   %% This is the time when the fault occurs
clearing_time = 3/60;        %% This is the time of clearance after the fault
has occurred
endtime = 101;    %% t=t+1
h = 1/1000;   %% Step size for simulation

X_d(2:4,1)=1.8*100/900;
X_q(2:4,1)=1.7*100/900;
X_l(2:4,1)=0.2*100/900;
X_dp(2:4,1)=0.3*100/900;
X_qp(2:4,1)=0.55*100/900;
X_dpp(2:4,1)=0.25*100/900;
X_qpp(2:4,1)=0.25*100/900;
R_a(2:4,1)=0;
T_d0p(2:4,1)=8.0;
T_q0p(2:4,1)=0.4;
T_d0pp(2:4,1)=0.03;
T_q0pp(2:4,1)=0.05;
A_sat(2:4,1)=0.015; % what's this
B_sat(2:4,1)=9.6;   % what's this
psi_t1(2:4,1)=0.9;
H(1)=6.5*900/100;
H(2)=6.5*900/100;
H(3)=6.175*900/100;
H(4)=6.175*900/100;
K_D(2:4,1)=2*900/100;

X=(X_d+X_q)/2;
X_p=(X_dp+X_qp)/2;
ws=2*pi*60;
no_of_states = 2;

%% read grid data from file
file_name='b_kundur_system.txt';
[S_Base,No_of_Buses,No_of_Lines,Bus_data,Line_data]=read_data(file_name);
[PQ,nPQ,PV,nPV,Y_mat,V_mag,V_Delta,P_gen_cal,Q_gen_cal, V_result]=
NR_power_flow(S_Base,No_of_Buses,No_of_Lines,Bus_data,Line_data);

%% revise y matrix, and form y_gen
file_name_2='b_kundur_system_extended.txt';
[S_Base_2,No_of_Buses_2,No_of_Lines_2,Bus_data_2,Line_data_2]=read_data(file_
name_2);
[Y_mat_ex,Theta_ex,Y_mag_ex,B_ex,G_ex]=y_bus(Bus_data_2,Line_data_2,No_of_Bus
es_2,No_of_Lines_2);

% yl7=(9.67-1j)/V_mag(7)^2;
% yl9=(17.67-1j)/V_mag(9)^2;
[Y_gen,Y_gen_mag,Y_gen_angle]=Ygen(Y_mat_ex,4,10);
```

```
%% solving for equilibrium point at t=0
S=complex(P_gen_cal, Q_gen_cal);
I=conj(S./(V_mag.*cos(V_Delta)+1i.*V_mag.*sin(V_Delta)));
I_mag=abs(I);
I_angle=angle(I);
E_p=zeros(4,1);
for i=1:4
E_p(i)=complex(V_mag(i)*cos(V_Delta(i)),V_mag(i).*sin(V_Delta(i)))+I(i).*(R_a
(i)+1i.*X_p(i));
end
% Y_gen_mag=abs(Y_gen);
% Y_gen_angle=angle(Y_gen); %returns the phase angles in radians
E_p_mag=abs(E_p);
E_p_angle=angle(E_p);
theta_0=E_p_angle;
w_0(1:4,1)=1; %initialize omega
[Pe_0]=Pe_type3(Y_gen_mag,Y_gen_angle,E_p_mag,theta_0,nPV,PV);
Pm_0=Pe_0;

%% prefault
iter=1;
for iteration=1:h:fault_time
    [theta_0,w_0]=type3_euler(Pe_0, Pm_0, PV,
nPV,H,Y_gen_mag,Y_gen_angle,E_p_mag,theta_0,w_0,ws,K_D,h);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=w_0;
    Pm(:,iter)=Pm_0;
    Vplot(:,iter)=V_mag(:,1);
    deltaplot(:,iter)=V_Delta(:,1);
    iter=iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end

%% onfault
% revise y matrix, and form y_gen
file_name_3='onfault_b_kundur_system_extended.txt';
[S_Base_3,No_of_Buses_3,No_of_Lines_3,Bus_data_3,Line_data_3]=read_data(file_
name_3);
[Y_mat_ex_f,Theta_ex_f,Y_mag_ex_f,B_ex_f,G_ex_f]=y_bus(Bus_data_3,Line_data_3
,No_of_Buses_3,No_of_Lines_3);
[Y_gen_f,Y_gen_mag_f,Y_gen_angle_f]=Ygen(Y_mat_ex_f,4,11);

for iteration=fault_time:h:(fault_time+clearing_time)
    [theta_0,w_0]=type3_euler(Pe_0, Pm_0, PV, nPV,H,Y_gen_mag_f,...
        Y_gen_angle_f,E_p_mag,theta_0,w_0,ws,K_D,h);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=w_0;
    Pm(:,iter)=Pm_0;
    Vplot(:,iter)=V_mag(:,1);
deltaplot(:,iter)=V_Delta(:,1);
iter = iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end
```

```
%% post fault analysis
% revise y matrix, and form y_gen
file_name_4='postfault_b_kundur_system_extended.txt';
[S_Base_4,No_of_Buses_4,No_of_Lines_4,Bus_data_4,Line_data_4]=read_data(file_
name_4);
[Y_mat_ex_pf,Theta_ex_pf,Y_mag_ex_pf,B_ex_pf,G_ex_pf]=y_bus(Bus_data_4,Line_d
ata_4,No_of_Buses_4,No_of_Lines_4);
[Y_gen_pf,Y_gen_mag_pf,Y_gen_angle_pf]=Ygen(Y_mat_ex_pf,4,10);

for iteration=(fault_time+clearing_time):h:endtime
    [theta_0,w_0]=type3_euler(Pe_0, Pm_0, PV, nPV,H,Y_gen_mag_pf,...
        Y_gen_angle_pf,E_p_mag,theta_0,w_0,ws,K_D,h);
    time(iter,1)=iteration-1;
    theta(:,iter)=theta_0;
    w(:,iter)=w_0;
    Pm(:,iter)=Pm_0;
    Vplot(:,iter)=V_mag(:,1);
deltaplot(:,iter)=V_Delta(:,1);
iter = iter+1;
end
iter=iter-1; %% To delete the extra time step added at the end

%% plot graphs

for e=1:nPV
    i=PV(e);
figure(e)
subplot(2,1,1)
plot(time,rad2deg(theta(i,:)),'linewidth',1.5)
title(['Generator ' num2str(i) ' Type 3 model (clearing time = '
num2str(clearing_time*60) ' cycles)' ]),'FontSize',13);
ylabel('\theta','FontSize',12,'FontWeight','bold');
subplot(2,1,2)
plot(time,w(i,:),'linewidth',1.5)
ylabel('\omega','FontSize',14,'FontWeight','bold');

end
```