**EE 523 | Spring 2023**

**Assignment 01**

**Submitted by**

**Sajjad Uddin Mahmud**

**WSU ID: 011789534**

**Logo, company name

Description automatically generated**

Code:

# Platform: MATLAB

## Main Code :

%% EE 523 Assignment 01 - Sajjad Uddin Mahmud - Spring 2023 - WSU

%% Basic Initialization

clc;

clear all;

close all;

%% Setting Up The Input Data As Per Assignment

Problem = 'A';

if Problem == 'A'

Excel\_Worksheet = 'Problem\_A';

elseif Problem == 'B'

Excel\_Worksheet = 'Problem\_B';

elseif Problem == 'C'

Excel\_Worksheet = 'Problem\_C';

end

%% Reading From Bus Data

%% Bus Number

All\_Bus\_Number = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'A4:A14'); % Reading All Bus ID Data

Total\_Bus = length(All\_Bus\_Number); % Calculating Total Bus Number

%% Bus Type

All\_Bus\_Type = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'G4:G14'); % Reading All Bus Type Data

PQ\_Bus\_Type = 0;

PQ\_Bus\_Type\_1 = 1;

PV\_Bus\_Type = 2;

Slack\_Bus\_Type = 3;

Bus = All\_Bus\_Number(find(All\_Bus\_Type ~= Slack\_Bus\_Type)); % Bus Type Data Except the Slack Bus

Bus\_Type = All\_Bus\_Type(Bus); % Bus Type Data Except the Slack Bus

%% Bus Information

% Slack\_Bus\_Number = 1

Base\_MVA = 100;

V\_Desired = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'O4:O14'); % Given Desired Voltage

Delta\_in\_Rad = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'I4:I14'); % Given Voltage Angle

P\_Load = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'J4:J14')/Base\_MVA; % Load MW pu

Q\_Load = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'K4:K14')/Base\_MVA; % Load MVAR pu

P\_Gen = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'L4:L14')/Base\_MVA; % Generator MW pu

Q\_Gen = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'M4:M14')/Base\_MVA; % Generator MVAR pu

%% Reading from Branch Data

%% Branch Number

From\_Bus = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'A18:A27');

To\_Bus = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'B18:B27');

%% Bus Shunt Conductance and Shunt Susceptance

G\_Shunt\_Bus = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'R4:R14');

B\_Shunt\_Bus = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'S4:S14');

%% Calculating Bus Shunt Admittance

Y\_Shunt\_Bus = G\_Shunt\_Bus + j.\*B\_Shunt\_Bus;

%% Branch Resistance Per Unit

R\_Branch = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'G18:G27');

%% Branch Reactance Per Unit

X\_Branch = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'H18:H27');

%% Line Charging B Per Unit

B\_Branch = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'I18:I27');

%% Transformer Turns Ratio

XFR\_TurnRatio = xlsread('Kundur\_Two\_Area\_System.xlsx',Excel\_Worksheet,'O18:O27');

%% Calculating Branch Impedence and Admittance

for i=1:length(From\_Bus)

Z\_Branch(i) = R\_Branch(i) + j \* X\_Branch(i); % Per Unit Impedance

Y\_Branch(i) = 1 / Z\_Branch(i); % Per Unit Admittance

end

%% Tap Consideration

Tap\_Consideration = 1; % 0 = Without Taps, 1 = With Taps

if (Tap\_Consideration == 0)

for i = 1:length(XFR\_TurnRatio)

XFR\_TurnRatio(i) = 0; % If We Do Not Consider Tap, All the Turn Ratio of Transformer are 0

end

end

%% Calculating Y Bus Matrix:

% Initialization

Y\_Bus = zeros(Total\_Bus,Total\_Bus);

% LOOP: Computing Off-Diagonal Elements

for i=1:length(Y\_Branch)

if (XFR\_TurnRatio(i)==0)

Y\_Bus(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i);

Y\_Bus(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i);

Y\_Bus\_Diag(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i);

Y\_Bus\_Diag(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i);

else

T = (1/(XFR\_TurnRatio(i)));

Y\_Bus(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i) \* (T);

Y\_Bus(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i) \* (T);

Y\_Bus\_Diag(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i);

Y\_Bus\_Diag(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i) \* (T^2);

end

end

% LOOP: Computing Diagonal Elements

Y\_Bus\_Sum = sum(Y\_Bus\_Diag);

for i=1:Total\_Bus

Y\_Bus(i,i) = -Y\_Bus\_Sum(i) + Y\_Shunt\_Bus(i); % Adding Shunt Capacitance

end

% LOOP: Adding Line Charaging Capacitance

for i=1:length(From\_Bus)

Y\_Bus(From\_Bus(i),From\_Bus(i)) = Y\_Bus(From\_Bus(i),From\_Bus(i)) + j \* (B\_Branch(i) / 2);

Y\_Bus(To\_Bus(i),To\_Bus(i)) = Y\_Bus(To\_Bus(i),To\_Bus(i)) + j \* (B\_Branch(i) / 2);

end

% Converting Y Bus Data into Polar Form

Rho = abs(Y\_Bus); % Magnitude of Y Bus Entries

Theta = angle(Y\_Bus); % Angle of Y Bus Entries in radian

B = imag(Y\_Bus); % Imaginary Part of Y Bus Entries

G = real(Y\_Bus); % Real Part of Y Bus Entries

% End of Y Bus Formation. Y Bus is Ready

%% Power Flow

%% Method

Task = 1; % Newton-Raphson = 1; Fast Decoupled = 2

%% Power Flow - Newton-Raphson Method

if Task == 1

[V, Delta\_in\_Rad, Iteration] = Newton\_Raphson\_Function(Y\_Bus, V\_Desired, Delta\_in\_Rad, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type);

%% Power Flow - Fast Decoupled

elseif Task == 2

[V\_FD, Delta\_in\_Rad\_FD, Iteration\_FD] = Newton\_Raphson\_Function\_1(Y\_Bus, V\_Desired, Delta\_in\_Rad, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type); % Putting Values after 4 Iterations of NR as Input for Fast Decoupled

V\_FD = transpose(V\_FD);

Delta\_in\_Rad\_FD = transpose(Delta\_in\_Rad\_FD);

[V, Delta\_in\_Rad, Iteration] = Fast\_Decoupled\_Function(Y\_Bus, V\_FD, Delta\_in\_Rad\_FD, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type);

end

## Function - Newton-Raphson:

%% EE 523 Assignment 01 - Sajjad Uddin Mahmud - Spring 2023 - WSU

%% Basic Initialization

clc;

clear all;

close all;

%% Setting Up The Input Data As Per Assignment

Problem = 'A';

if Problem == 'A'

Excel\_Worksheet = 'Problem\_A';

elseif Problem == 'B'

Excel\_Worksheet = 'Problem\_B';

elseif Problem == 'C'

Excel\_Worksheet = 'Problem\_C';

end

%% Reading From Bus Data

%% Bus Number

All\_Bus\_Number = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'A4:A14'); % Reading All Bus ID Data

Total\_Bus = length(All\_Bus\_Number); % Calculating Total Bus Number

%% Bus Type

All\_Bus\_Type = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'G4:G14'); % Reading All Bus Type Data

PQ\_Bus\_Type = 0;

PQ\_Bus\_Type\_1 = 1;

PV\_Bus\_Type = 2;

Slack\_Bus\_Type = 3;

Bus = All\_Bus\_Number(find(All\_Bus\_Type ~= Slack\_Bus\_Type)); % Bus Type Data Except the Slack Bus

Bus\_Type = All\_Bus\_Type(Bus); % Bus Type Data Except the Slack Bus

%% Bus Information

% Slack\_Bus\_Number = 1

Base\_MVA = 100;

V\_Desired = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'O4:O14'); % Given Desired Voltage

Delta\_in\_Rad = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'I4:I14'); % Given Voltage Angle

P\_Load = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'J4:J14')/Base\_MVA; % Load MW pu

Q\_Load = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'K4:K14')/Base\_MVA; % Load MVAR pu

P\_Gen = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'L4:L14')/Base\_MVA; % Generator MW pu

Q\_Gen = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'M4:M14')/Base\_MVA; % Generator MVAR pu

%% Reading from Branch Data

%% Branch Number

From\_Bus = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'A18:A27');

To\_Bus = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'B18:B27');

%% Bus Shunt Conductance and Shunt Susceptance

G\_Shunt\_Bus = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'R4:R14');

B\_Shunt\_Bus = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'S4:S14');

%% Calculating Bus Shunt Admittance

Y\_Shunt\_Bus = G\_Shunt\_Bus + j.\*B\_Shunt\_Bus;

%% Branch Resistance Per Unit

R\_Branch = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'G18:G27');

%% Branch Reactance Per Unit

X\_Branch = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'H18:H27');

%% Line Charging B Per Unit

B\_Branch = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'I18:I27');

%% Transformer Turns Ratio

XFR\_TurnRatio = xlsread('Kundur\_11Bus\_System.xlsx',Excel\_Worksheet,'O18:O27');

%% Calculating Branch Impedence and Admittance

for i=1:length(From\_Bus)

Z\_Branch(i) = R\_Branch(i) + j \* X\_Branch(i); % Per Unit Impedance

Y\_Branch(i) = 1 / Z\_Branch(i); % Per Unit Admittance

end

%% Tap Consideration

Tap\_Consideration = 1; % 0 = Without Taps, 1 = With Taps

if (Tap\_Consideration == 0)

for i = 1:length(XFR\_TurnRatio)

XFR\_TurnRatio(i) = 0; % If We Do Not Consider Tap, All the Turn Ratio of Transformer are 0

end

end

%% Calculating Y Bus Matrix:

% Initialization

Y\_Bus = zeros(Total\_Bus,Total\_Bus);

% LOOP: Computing Off-Diagonal Elements

for i=1:length(Y\_Branch)

if (XFR\_TurnRatio(i)==0)

Y\_Bus(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i);

Y\_Bus(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i);

Y\_Bus\_Diag(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i);

Y\_Bus\_Diag(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i);

else

T = (1/(XFR\_TurnRatio(i)));

Y\_Bus(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i) \* (T);

Y\_Bus(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i) \* (T);

Y\_Bus\_Diag(From\_Bus(i),To\_Bus(i)) = - Y\_Branch(i);

Y\_Bus\_Diag(To\_Bus(i),From\_Bus(i)) = - Y\_Branch(i) \* (T^2);

end

end

% LOOP: Computing Diagonal Elements

Y\_Bus\_Sum = sum(Y\_Bus\_Diag);

for i=1:Total\_Bus

Y\_Bus(i,i) = -Y\_Bus\_Sum(i) + Y\_Shunt\_Bus(i); % Adding Shunt Capacitance

end

% LOOP: Adding Line Charaging Capacitance

for i=1:length(From\_Bus)

Y\_Bus(From\_Bus(i),From\_Bus(i)) = Y\_Bus(From\_Bus(i),From\_Bus(i)) + j \* (B\_Branch(i) / 2);

Y\_Bus(To\_Bus(i),To\_Bus(i)) = Y\_Bus(To\_Bus(i),To\_Bus(i)) + j \* (B\_Branch(i) / 2);

end

% Converting Y Bus Data into Polar Form

Rho = abs(Y\_Bus); % Magnitude of Y Bus Entries

Theta = angle(Y\_Bus); % Angle of Y Bus Entries in radian

B = imag(Y\_Bus); % Imaginary Part of Y Bus Entries

G = real(Y\_Bus); % Real Part of Y Bus Entries

% End of Y Bus Formation. Y Bus is Ready

%% Power Flow

%% Method

Task = 1; % Newton-Raphson = 1; Fast Decoupled = 2

%% Power Flow - Newton-Raphson Method

if Task == 1

[V, Delta\_in\_Rad, Iteration] = Newton\_Raphson\_Function(Y\_Bus, V\_Desired, Delta\_in\_Rad, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type);

%% Power Flow - Fast Decoupled

elseif Task == 2

[V\_FD, Delta\_in\_Rad\_FD, Iteration\_FD] = Newton\_Raphson\_Function\_1(Y\_Bus, V\_Desired, Delta\_in\_Rad, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type); % Putting Values after 4 Iterations of NR as Input for Fast Decoupled

V\_FD = transpose(V\_FD);

Delta\_in\_Rad\_FD = transpose(Delta\_in\_Rad\_FD);

[V, Delta\_in\_Rad, Iteration] = Fast\_Decoupled\_Function(Y\_Bus, V\_FD, Delta\_in\_Rad\_FD, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type);

end

## Function - Newton-Raphson (For Getting Input of Fast Decoupled):

%% Power Flow Function: Newton-Raphson

function [V, Delta\_in\_Rad, Iteration] = Newton\_Raphson\_Function\_1(Y\_Bus, V\_Desired, Delta\_in\_Rad, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type)

%% Basic Initialization

Total\_Bus = length(All\_Bus\_Number);

PQ\_Bus\_Type = 0;

PQ\_Bus\_Type\_1 = 1;

PV\_Bus\_Type = 2;

Slack\_Bus\_Type = 3;

Bus = All\_Bus\_Number(find(All\_Bus\_Type ~= Slack\_Bus\_Type)); % Bus Type Data Except the Slack Bus

Bus\_Type = All\_Bus\_Type(Bus); % Bus Type Data Except the Slack Bus

Base\_MVA = 100;

%% Power Flow

% Schedule Real and Reactive Power

P\_Scheduled = transpose(P\_Gen - P\_Load);

Q\_Scheduled = transpose(Q\_Gen - Q\_Load);

% Initial Voltage Magnitude

V = ones(1,length(All\_Bus\_Number));

V(1,find(V\_Desired)) = V\_Desired(find(V\_Desired),1);

% Initialization

Iteration = 0;

Tolerance = 0.01;

while 1

%% Calculating Real Power

% Initialization

P\_Calculated = zeros(1,Total\_Bus);

% LOOP: Computing Real Power

for i=1:Total\_Bus

for n=1:Total\_Bus

P\_Calculated(i) = P\_Calculated(i) + (abs(abs(Y\_Bus(i,n)) \* V(i) \* V(n))) \* (cos(angle(Y\_Bus(i,n)) + Delta\_in\_Rad(n) - Delta\_in\_Rad(i)));

end

end

%% Calculating Reactive Power

% Initialization

Q\_Calculated = zeros(1,Total\_Bus);

% LOOP: Computing Reactive Power

for i=1:Total\_Bus

for n=1:Total\_Bus

Q\_Calculated(i) = Q\_Calculated(i) + (abs(abs(Y\_Bus(i,n)) \* V(i) \* V(n))) \* (sin(angle(Y\_Bus(i,n)) + Delta\_in\_Rad(n) - Delta\_in\_Rad(i)));

end

Q\_Calculated(i) = - Q\_Calculated(i);

end

%% Calculating Mismatch

Delta\_P = P\_Scheduled - P\_Calculated;

Delta\_Q = Q\_Scheduled - Q\_Calculated;

% Initializating Jacobian Matrix

J11 = zeros(length(Bus));

J12 = zeros(length(Bus));

J21 = zeros(length(Bus));

J22 = zeros(length(Bus));

% LOOP: Computing Jacobian Matrix for All the Buses Except Slack Bus

for i=1:length(Bus)

for j=1:length(Bus)

if (i==j)

J11(i,j) = - Q\_Calculated(Bus(i)) - ((V(Bus(i)))^2) \* (imag(Y\_Bus(Bus(i),Bus(i))));

J21(i,j) = P\_Calculated(Bus(i)) - ((V(Bus(i)))^2) \* (real(Y\_Bus(Bus(i),Bus(i))));

J12(i,j) = P\_Calculated(Bus(i)) + ((V(Bus(i)))^2) \* (real(Y\_Bus(Bus(i),Bus(i))));

J22(i,j) = Q\_Calculated(Bus(i)) - ((V(Bus(i)))^2) \* (imag(Y\_Bus(Bus(i),Bus(i))));

else

J11(i,j) = - abs(V(Bus(i)) \* V(Bus(j)) \* abs(Y\_Bus(Bus(i),Bus(j)))) \* sin(angle(Y\_Bus(Bus(i),Bus(j))) + Delta\_in\_Rad(Bus(j)) - Delta\_in\_Rad(Bus(i)));

J21(i,j) = - abs(V(Bus(i)) \* V(Bus(j)) \* abs(Y\_Bus(Bus(i),Bus(j)))) \* cos(angle(Y\_Bus(Bus(i),Bus(j))) + Delta\_in\_Rad(Bus(j)) - Delta\_in\_Rad(Bus(i)));

J12(i,j) = - J21(i,j);

J22(i,j) = J11(i,j);

end

end

end

% Removing Rows and Columns from Jacobian for PV Bus

PV = find(Bus\_Type==PV\_Bus\_Type);

J12(:,PV) = [];

J21(PV,:) = [];

J22(:,PV) = [];

J22(PV,:) = [];

J = [J11 J12; J21 J22];

% Delta

Delta\_J = Delta\_in\_Rad(find(All\_Bus\_Type ~= Slack\_Bus\_Type));

V\_J = V(find((All\_Bus\_Type == PQ\_Bus\_Type)));

Delta\_P\_J = Delta\_P(find(All\_Bus\_Type ~= Slack\_Bus\_Type));

Delta\_Q\_J = Delta\_Q(find((All\_Bus\_Type == PQ\_Bus\_Type)));

Delta\_P\_Q = [transpose(Delta\_P\_J);transpose(Delta\_Q\_J)];

%% Updating V and Delta through LU Factorization

% Function Calling: LU Factorization Using Dolittle's Method

[V\_Delta\_Corrected] = LU\_Factorization\_Dolittle\_Function(J,Delta\_P\_Q);

% LOOP: Sorting the Voltages and Angles after LU Factorization

for i=1:length(V\_Delta\_Corrected)

if (i <= length(Delta\_P\_J))

Delta\_Corrected(i) = V\_Delta\_Corrected(i);

else

V\_Corrected(i-length(Delta\_P\_J)) = V\_Delta\_Corrected(i);

end

end

% Updating Voltages and Angles

Delta\_Updated = Delta\_J + Delta\_Corrected;

V\_Updated = V\_J .\* (1 + V\_Corrected);

% Preparing for Next Iteration

V\_i = (find((All\_Bus\_Type == PQ\_Bus\_Type)));

Delta\_i = find(All\_Bus\_Type ~= Slack\_Bus\_Type);

for i=1:length(Delta\_i)

Delta\_New(Delta\_i(i)) = Delta\_Updated(i);

end

for i=1:length(V\_i)

V\_Desired(V\_i(i)) = V\_Updated(i);

end

V = transpose(V\_Desired);

Delta\_in\_Rad = Delta\_New;

Delta\_in\_Degree = (180 / pi) \* Delta\_in\_Rad;

Iteration = Iteration + 1;

%% Output

%fprintf("YBus: \n")

%Y\_Bus

%fprintf("Number of Iteration: \n");

%Iteration

%fprintf("Voltage Magnitude: \n")

%V

%fprintf("Voltage Angles in Degree: \n")

%Delta\_in\_Degree

%fprintf("Real Power in MW: \n")

%P\_Calculated \* Base\_MVA

%fprintf("Reactive Power in MVAR: \n")

%Q\_Calculated \* Base\_MVA

% Checking Iteration Limit

if (Iteration == 4)

break;

end

end

% This does not converge; this is just to get a certain iterated values which are used as a input of Fast Decoupled Function to make that converge.

## Function - Fast Decoupled:

%% Power Flow Function: Fast Decoupled

function [V, Delta\_in\_Rad, Iteration] = Fast\_Decoupled\_Function(Y\_Bus, V\_Desired, Delta\_in\_Rad, P\_Gen, P\_Load, Q\_Gen, Q\_Load, All\_Bus\_Number, All\_Bus\_Type)

%% Basic Initialization

Total\_Bus = length(All\_Bus\_Number);

PQ\_Bus\_Type = 0;

PQ\_Bus\_Type\_1 = 1;

PV\_Bus\_Type = 2;

Slack\_Bus\_Type = 3;

Bus = All\_Bus\_Number(find(All\_Bus\_Type ~= Slack\_Bus\_Type)); % Bus Type Data Except the Slack Bus

Bus\_Type = All\_Bus\_Type(Bus); % Bus Type Data Except the Slack Bus

Base\_MVA = 100;

%% Power Flow

% Schedule Real and Reactive Power

P\_Scheduled = transpose(P\_Gen - P\_Load);

Q\_Scheduled = transpose(Q\_Gen - Q\_Load);

% Initial Voltage Magnitude

V = ones(1,length(All\_Bus\_Number));

V(1,find(V\_Desired)) = V\_Desired(find(V\_Desired),1);

% Initialization

Iteration = 0;

Tolerance = 0.01;

while 1

%% Calculating Real Power

% Initialization

P\_Calculated = zeros(1,Total\_Bus);

% LOOP: Computing Real Power

for i=1:Total\_Bus

for n=1:Total\_Bus

P\_Calculated(i) = P\_Calculated(i) + (abs(abs(Y\_Bus(i,n)) \* V(i) \* V(n))) \* (cos(angle(Y\_Bus(i,n)) + Delta\_in\_Rad(n) - Delta\_in\_Rad(i)));

end

end

%% Calculating Reactive Power

% Initialization

Q\_Calculated = zeros(1,Total\_Bus);

% LOOP: Computing Reactive Power

for i=1:Total\_Bus

for n=1:Total\_Bus

Q\_Calculated(i) = Q\_Calculated(i) + (abs(abs(Y\_Bus(i,n)) \* V(i) \* V(n))) \* (sin(angle(Y\_Bus(i,n)) + Delta\_in\_Rad(n) - Delta\_in\_Rad(i)));

end

Q\_Calculated(i) = - Q\_Calculated(i);

end

%% Calculating Mismatch

Delta\_P = P\_Scheduled - P\_Calculated;

Delta\_Q = Q\_Scheduled - Q\_Calculated;

% Initialization of Jacobian in Fast Decoupled Method; J12=J21=0

J11 = zeros(length(Bus));

J22 = zeros(length(Bus));

% LOOP: Computing Jacobian Matrix for All the Buses Except Slack Bus

for i=1:length(Bus)

for j=1:length(Bus)

J11(i,j) = - (imag(Y\_Bus(Bus(i),Bus(j))));

J22(i,j) = - (imag(Y\_Bus(Bus(i),Bus(j))));

end

end

% Removing Rows and Columns from Jacobian for PV Bus

PV = find(Bus\_Type == PV\_Bus\_Type);

J22(:,PV) = [];

J22(PV,:) = [];

% Delta

Delta\_J = Delta\_in\_Rad(find(All\_Bus\_Type ~= Slack\_Bus\_Type));

V\_J = V(find((All\_Bus\_Type == PQ\_Bus\_Type)));

Delta\_P\_J = Delta\_P(find(All\_Bus\_Type ~= Slack\_Bus\_Type));

Delta\_Q\_J = Delta\_Q(find((All\_Bus\_Type == PQ\_Bus\_Type)));

%% Updating V and Delta through LU Factorization

% Function Calling: LU Factorization Using Dolittle's Method

[Delta\_Corrected] = LU\_Factorization\_Dolittle\_Function(J11,Delta\_P\_J);

[V\_Corrected] = LU\_Factorization\_Dolittle\_Function(J22,Delta\_Q\_J);

% Updating Voltages and Angles

Delta\_Updated = Delta\_J + transpose(Delta\_Corrected);

V\_Updated = V\_J.\*(1 + transpose(V\_Corrected));

% Preparing for Next Iteration

V\_i = (find((All\_Bus\_Type == PQ\_Bus\_Type)));

Delta\_i = find(All\_Bus\_Type ~= Slack\_Bus\_Type);

for i=1:length(Delta\_i)

Delta\_New(Delta\_i(i)) = Delta\_Updated(i);

end

for i=1:length(V\_i)

V\_Desired(V\_i(i)) = V\_Updated(i);

end

V = transpose(V\_Desired);

Delta\_in\_Rad = Delta\_New;

Delta\_in\_Degree = (180 / pi) \* Delta\_in\_Rad;

Iteration = Iteration + 1;

%% Output

%fprintf("YBus: \n")

%Y\_Bus

fprintf("Number of Iteration: \n")

Iteration

fprintf("Voltage Magnitude: \n")

V

fprintf("Voltage Angles in Degree: \n")

Delta\_in\_Degree

fprintf("Real Power in MW: \n")

P\_Calculated \* Base\_MVA

fprintf("Reactive Power in MVAR: \n")

Q\_Calculated \* Base\_MVA

% Checking Tolerance Limit

if (max(abs(Delta\_P\_J)) < Tolerance & max(abs(Delta\_Q\_J)) < Tolerance)

break;

end

end

end

## Function – LU Factorization:

%% LU Factorization Function: Dolittle's Algorithm

function [ X\_Matrix ] = LU\_Factorization\_Dolittle\_Function(A\_Matrix,B\_Matrix)

% Getting the Size of Input Matrix

Length\_A = length(A\_Matrix);

% Initializing The Lower and Upper Triangular Matrices

Lower\_Triangular\_Matrix = zeros(Length\_A,Length\_A);

Upper\_Triangular\_Matrix = zeros(Length\_A,Length\_A);

% LOOP: Assigning 1 into All Diagonal Elements of Lower Traingular Matrix

for j = 1:Length\_A

Lower\_Triangular\_Matrix(j,j) = 1;

end

% Computing 1st Row of Upper Traingular Matrix

Upper\_Triangular\_Matrix(1,:) = A\_Matrix(1,:);

% Computing 1st Column of Lower Traingular Matrix

Lower\_Triangular\_Matrix(:,1) = A\_Matrix(:,1)/Upper\_Triangular\_Matrix(1,1);

% LOOP: Computing All Other Rows and Column of Upper and Lower Traingular Matrix

for j = 2:Length\_A

for k = j:Length\_A

Upper\_Triangular\_Matrix(j,k) = A\_Matrix(j,k) - Lower\_Triangular\_Matrix(j,1:j-1) \* Upper\_Triangular\_Matrix(1:j-1,k);

end

for l = j+1:Length\_A

Lower\_Triangular\_Matrix(l,j) = (A\_Matrix(l,j) - Lower\_Triangular\_Matrix(l,1:j-1) \* Upper\_Triangular\_Matrix(1:j-1,j)) / Upper\_Triangular\_Matrix(j,j);

end

end

% Output

% A\_Matrix

% Lower\_Triangular\_Matrix

% Upper\_Triangular\_Matrix

% Verification

% A\_Matrix - (Lower\_Triangular\_Matrix \* Upper\_Triangular\_Matrix)

%% Forward Substitution

% Initialization of Y Matrix

Y\_Matrix = zeros(Length\_A,1);

% Computing First Value of Y Matrix

Y\_Matrix(1) = B\_Matrix(1) / Lower\_Triangular\_Matrix(1,1);

% LOOP: Computing Rest of the Entries of Y Matrix

for j = 2:Length\_A

Y\_Matrix(j) = (B\_Matrix(j) - Lower\_Triangular\_Matrix(j,1:j-1) \* Y\_Matrix(1:j-1)) / Lower\_Triangular\_Matrix(j,j);

end

% Output

% Y\_Matrix

%% Backward Substitution

% Initialization of X Matrix

X\_Matrix = zeros(Length\_A,1);

% Computing Last Value of X Matrix

X\_Matrix(Length\_A) = Y\_Matrix(Length\_A) / Upper\_Triangular\_Matrix(Length\_A,Length\_A);

% LOOP: Computing Rest of the Entries of X Matrix

for j = Length\_A-1:-1:1

X\_Matrix(j) = (Y\_Matrix(j) - Upper\_Triangular\_Matrix(j,j+1:Length\_A) \* X\_Matrix(j+1:Length\_A)) / Upper\_Triangular\_Matrix(j,j);

end

% Output

% X\_Matrix

end

Results:

# Problem A:

## Newton-Raphson Method

Number of Iteration:

Iteration =

1

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0649 1.0473 1.0550 1.0709 1.0627 1.0472 1.0451

Voltage Angles in Degree:

Delta\_in\_Degree =

0 14.1978 14.1978 14.1978 14.1978 14.1978 14.1978 14.1978 14.1978 14.1978 14.1978

Real Power in MW:

ans =

1.0e+03 \*

2.1297 0.0000 0.0000 0.0000 -2.1297 -0.0000 -0.0000 -0.0000 -0.0000 -0.0000 0.0000

Reactive Power in MVAR:

ans =

564.3918 60.4790 185.0299 60.4790 197.5336 -62.9427 -220.1250 -38.5000 -370.1250 -62.9427 -181.8282

Number of Iteration:

Iteration =

2

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0786 1.0514 1.0584 1.0708 1.0604 1.0454 1.0433

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -7.5255 -16.9800 -26.5538 -6.0226 -13.8575 -20.7846 -30.6625 -40.3464 -32.8865 -23.3708

Real Power in MW:

ans =

1.0e+03 \*

-1.6110 0.0000 0.0000 0.0000 1.6184 -0.0153 0.0050 0.0047 0.0147 -0.0152 -0.0009

Reactive Power in MVAR:

ans =

-14.9118 -225.6061 -93.3520 -224.9557 495.4177 77.9557 -195.2449 2.4574 -270.8618 77.9340 83.8079

Number of Iteration:

Iteration =

3

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0130 0.9869 0.9737 0.9662 0.9822 0.9902 1.0113

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.2934 -24.4828 -34.5837 -6.3573 -16.0038 -24.0732 -36.8897 -49.4874 -41.2760 -31.0950

Real Power in MW:

ans =

1.0e+03 \*

0.6980 0.7013 0.7163 0.6974 -0.0699 0.0089 -0.9629 0.0042 -1.7429 0.0141 0.0029

Reactive Power in MVAR:

ans =

-263.0013 -211.7455 -42.0610 -175.5967 444.7931 161.3176 11.3574 59.5464 20.8568 191.2985 100.0204

Number of Iteration:

Iteration =

4

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0065 0.9783 0.9614 0.9493 0.9717 0.9836 1.0083

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.7515 -26.9668 -37.1552 -6.4717 -16.5450 -24.9426 -38.7659 -52.3211 -43.9124 -33.6059

Real Power in MW:

ans =

1.0e+03 \*

0.6918 0.6974 0.7182 0.6979 -0.0123 -0.0077 -0.9575 0.0012 -1.7389 -0.0079 -0.0025

Reactive Power in MVAR:

ans =

143.4928 180.8507 156.6653 160.5378 27.2058 10.9940 -90.4928 7.0786 -92.3724 10.0843 3.1147

Number of Iteration:

Iteration =

5

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0064 0.9780 0.9609 0.9485 0.9713 0.9834 1.0082

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.7682 -27.0918 -37.2827 -6.4765 -16.5647 -24.9764 -38.8538 -52.4583 -44.0420 -33.7317

Real Power in MW:

ans =

1.0e+03 \*

0.6997 0.6999 0.7190 0.7000 -0.0003 -0.0005 -0.9668 0.0001 -1.7657 -0.0004 -0.0001

Reactive Power in MVAR:

ans =

184.2368 232.9942 175.6173 200.8981 0.2747 0.2809 -99.6393 0.4408 -99.8420 0.1133 0.0149

Number of Iteration:

Iteration =

6

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0064 0.9780 0.9609 0.9485 0.9713 0.9834 1.0082

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.7682 -27.0921 -37.2830 -6.4765 -16.5647 -24.9765 -38.8540 -52.4586 -44.0423 -33.7320

Real Power in MW:

ans =

1.0e+03 \*

0.7001 0.7000 0.7190 0.7000 -0.0000 -0.0000 -0.9670 0.0000 -1.7670 -0.0000 -0.0000

Reactive Power in MVAR:

ans =

185.3260 234.9443 176.2393 202.3613 0.0002 0.0004 -99.9991 0.0013 -99.9997 0.0001 0.0000

# Problem A:

## Fast Decoupled Method

As Fast Decoupled method was not converging with initial condition, first I have run Newton-Raphson and took the 4th iteration results as the input of the Fast Decoupled function.

Number of Iteration:

Iteration =

1

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0065 0.9782 0.9612 0.9490 0.9716 0.9835 1.0083

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.8011 -27.0164 -37.2048 -6.5214 -16.5946 -24.9922 -38.8156 -52.3707 -43.9621 -33.6556

Real Power in MW:

ans =

1.0e+03 \*

0.6997 0.6999 0.7190 0.7000 -0.0003 -0.0005 -0.9668 0.0001 -1.7657 -0.0004 -0.0001

Reactive Power in MVAR:

ans =

184.2368 232.9942 175.6173 200.8981 0.2747 0.2809 -99.6393 0.4408 -99.8420 0.1133 0.0149

Number of Iteration:

Iteration =

2

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0064 0.9782 0.9612 0.9490 0.9716 0.9835 1.0083

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.7698 -27.0880 -37.2776 -6.4764 -16.5648 -24.9734 -38.8471 -52.4486 -44.0358 -33.7274

Real Power in MW:

ans =

1.0e+03 \*

0.7050 0.6998 0.7190 0.6999 -0.0057 -0.0007 -0.9666 0.0001 -1.7653 -0.0005 -0.0001

Reactive Power in MVAR:

ans =

185.2990 233.6724 175.8017 201.3188 0.5927 -0.0116 -99.9719 0.0358 -100.0220 -0.0069 -0.0068

Number of Iteration:

Iteration =

3

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0064 0.9781 0.9610 0.9486 0.9713 0.9834 1.0082

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.7572 -27.0336 -37.2232 -6.4720 -16.5525 -24.9582 -38.8134 -52.3945 -43.9814 -33.6730

Real Power in MW:

ans =

1.0e+03 \*

0.7001 0.7000 0.7190 0.7000 0.0001 -0.0000 -0.9669 0.0001 -1.7672 -0.0000 -0.0000

Reactive Power in MVAR:

ans =

185.1895 233.8677 175.8054 201.3400 -0.4829 0.3788 -99.3538 0.6714 -99.3918 0.0781 0.0138

# Problem B:

## Newton-Raphson Method

Number of Iteration:

Iteration =

1

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0785 1.0791 1.1129 1.1159 1.0877 1.0609 1.0507

Voltage Angles in Degree:

Delta\_in\_Degree =

0 14.3786 14.3786 14.3786 14.3786 14.3786 14.3786 14.3786 14.3786 14.3786 14.3786

Real Power in MW:

ans =

1.0e+03 \*

2.1297 0.0000 0.0000 0.0000 -2.1297 -0.0000 -0.0000 -0.0000 -0.0000 -0.0000 0.0000

Reactive Power in MVAR:

ans =

564.3918 60.4790 185.0299 60.4790 197.5336 -62.9427 -429.7500 -48.1250 -420.1250 -62.9427 -181.8282

Number of Iteration:

Iteration =

2

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0902 1.0792 1.1094 1.1103 1.0822 1.0572 1.0480

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -7.4147 -12.0427 -21.5297 -5.9529 -13.5601 -20.0598 -26.0288 -35.0276 -27.7806 -18.3995

Real Power in MW:

ans =

1.0e+03 \*

-1.6518 0.0000 0.0000 0.0000 1.6515 -0.0359 0.0364 0.0065 0.0234 -0.0239 -0.0042

Reactive Power in MVAR:

ans =

-90.7027 -418.0637 -127.8255 -307.8099 516.2356 84.4993 -168.5341 5.5693 -263.2220 80.7205 85.6615

Number of Iteration:

Iteration =

3

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0258 1.0185 1.0306 1.0208 1.0103 1.0058 1.0177

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -8.9805 -17.5408 -27.5382 -6.2213 -15.4844 -22.9949 -30.5796 -42.0688 -34.1288 -24.1122

Real Power in MW:

ans =

1.0e+03 \*

0.6974 0.6987 0.7157 0.6962 -0.0717 0.0010 -0.9539 0.0031 -1.7343 0.0102 0.0016

Reactive Power in MVAR:

ans =

-335.1018 -380.9067 -71.2751 -247.5230 453.6693 155.9044 -6.0536 44.8067 15.1052 188.0764 99.2187

Number of Iteration:

Iteration =

4

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0204 1.0119 1.0215 1.0098 1.0027 1.0009 1.0153

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.3345 -18.9802 -29.0487 -6.3048 -15.9017 -23.6471 -31.6541 -43.7776 -35.6891 -25.5732

Real Power in MW:

ans =

1.0e+03 \*

0.6857 0.6977 0.7183 0.6982 -0.0112 -0.0063 -0.9572 0.0006 -1.7435 -0.0069 -0.0023

Reactive Power in MVAR:

ans =

62.8989 -11.5286 117.3564 65.7442 26.7709 9.7786 -92.9328 4.6109 -93.2053 9.2082 2.9352

Number of Iteration:

Iteration =

5

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0203 1.0118 1.0213 1.0095 1.0025 1.0008 1.0153

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.3425 -19.0218 -29.0913 -6.3069 -15.9110 -23.6625 -31.6823 -43.8245 -35.7327 -25.6150

Real Power in MW:

ans =

1.0e+03 \*

0.6911 0.7000 0.7190 0.7000 -0.0002 -0.0003 -0.9668 0.0000 -1.7663 -0.0002 -0.0000

Reactive Power in MVAR:

ans =

97.3500 28.3703 131.8829 95.8365 0.2083 0.1747 -99.8397 0.1769 -99.8990 0.0743 0.0106

>>

# Problem B:

## Fast Decoupled Method

As Fast Decoupled method was not converging with initial condition, first I have run Newton-Raphson and took the 4th iteration results as the input of the Fast Decoupled function.

Number of Iteration:

Iteration =

1

Voltage Magnitude:

V =

1.0300 1.0100 1.0300 1.0100 1.0203 1.0119 1.0214 1.0096 1.0026 1.0008 1.0153

Voltage Angles in Degree:

Delta\_in\_Degree =

0 -9.3685 -19.0143 -29.0827 -6.3388 -15.9358 -23.6811 -31.6881 -43.8116 -35.7231 -25.6072

Real Power in MW:

ans =

1.0e+03 \*

0.6911 0.7000 0.7190 0.7000 -0.0002 -0.0003 -0.9668 0.0000 -1.7663 -0.0002 -0.0000

Reactive Power in MVAR:

ans =

97.3500 28.3703 131.8829 95.8365 0.2083 0.1747 -99.8397 0.1769 -99.8990 0.0743 0.0106

>>

# Problem C :

## Newton-Raphson Method

Both Newton-Raphson and Fast Decoupled is not converging.

Input Data:

# Problem A:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| BUS DATA FOLLOWS | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| BUS | | | | LOAD FLOW AREA | LOSS ZONE | TYPE | V\_MAG | V\_ANG | LOAD\_MW | LOAD\_MVA | G\_MW | G\_MVAR | BASE\_KV | V\_DESIRED | MAX MVAR/VOLT LIMIT | MIN MVAR/VOLT LIMIT | SHUNT\_G | SHUNT\_B | REMOTE CONTROLLED BUS |
| 1 | Bus | 1 | HV | 1 | 1 | 3 | 1.06 | 20.2 | 0 | 0 | 700 | 185 | 0 | 1.03 | 0 | 0 | 0 | 0 | 0 |
| 2 | Bus | 2 | HV | 1 | 1 | 2 | 1.045 | 10.5 | 0 | 0 | 700 | 235 | 0 | 1.01 | 0 | 0 | 0 | 0 | 0 |
| 3 | Bus | 3 | HV | 1 | 1 | 2 | 1.01 | -6.8 | 0 | 0 | 719 | 176 | 0 | 1.03 | 0 | 0 | 0 | 0 | 0 |
| 4 | Bus | 4 | HV | 1 | 1 | 2 | 1.019 | -17 | 0 | 0 | 700 | 202 | 0 | 1.01 | 0 | 0 | 0 | 0 | 0 |
| 5 | Bus | 5 | HV | 1 | 1 | 0 | 1.02 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 6 | Bus | 6 | LV | 1 | 1 | 0 | 1.07 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | Bus | 7 | ZV | 1 | 1 | 0 | 1.062 | 0 | 967 | 100 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 |
| 8 | Bus | 8 | TV | 1 | 1 | 0 | 1.09 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9 | Bus | 9 | LV | 1 | 1 | 0 | 1.056 | 0 | 1767 | 100 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3.5 | 0 |
| 10 | Bus | 10 | LV | 1 | 1 | 0 | 1.051 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 11 | Bus | 11 | LV | 1 | 1 | 0 | 1.057 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| BRANCH DATA FOLLOWS | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| FROM | TO | LOAD FLOW AREA | LOSS ZONE | CIRCUIT | TYPE | R | X | B | LINE MVA RATING 1 | LINE MVA RATING 2 | LINE MVA RATING 3 | CONTROL BUS | SIDE | XFR FINAL TURN RATIO | XFR FINAL ANGLE | MIN TAP.PHASE SHIFT | MAX TAP/PHASE SHIFT | STEP SIZE | MIN VOLT/MVAR MW LIMIT | MAX VOLT/MVAR MW LIMIT |
| 1 | 5 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 11 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 10 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 6 | 1 | 1 | 1 | 0 | 0.0025 | 0.025 | 0.04375 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 7 | 1 | 1 | 1 | 0 | 0.001 | 0.01 | 0.0175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 8 | 1 | 1 | 1 | 0 | 0.0055 | 0.055 | 0.385 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 9 | 1 | 1 | 1 | 0 | 0.0055 | 0.055 | 0.385 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 10 | 1 | 1 | 1 | 0 | 0.001 | 0.01 | 0.0175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 11 | 1 | 1 | 1 | 0 | 0.0025 | 0.025 | 0.04375 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Problem B:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| BUS DATA FOLLOWS | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| BUS | | | | LOAD FLOW AREA | LOSS ZONE | TYPE | V\_MAG | V\_ANG | LOAD\_MW | LOAD\_MVA | G\_MW | G\_MVAR | BASE\_KV | V\_DESIRED | MAX MVAR/VOLT LIMIT | MIN MVAR/VOLT LIMIT | SHUNT\_G | SHUNT\_B | REMOTE CONTROLLED BUS |
| 1 | Bus | 1 | HV | 1 | 1 | 3 | 1.06 | 20.2 | 0 | 0 | 700 | 185 | 0 | 1.03 | 0 | 0 | 0 | 0 | 0 |
| 2 | Bus | 2 | HV | 1 | 1 | 2 | 1.045 | 10.5 | 0 | 0 | 700 | 235 | 0 | 1.01 | 0 | 0 | 0 | 0 | 0 |
| 3 | Bus | 3 | HV | 1 | 1 | 2 | 1.01 | -6.8 | 0 | 0 | 719 | 176 | 0 | 1.03 | 0 | 0 | 0 | 0 | 0 |
| 4 | Bus | 4 | HV | 1 | 1 | 2 | 1.019 | -17 | 0 | 0 | 700 | 202 | 0 | 1.01 | 0 | 0 | 0 | 0 | 0 |
| 5 | Bus | 5 | HV | 1 | 1 | 0 | 1.02 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 6 | Bus | 6 | LV | 1 | 1 | 0 | 1.07 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | Bus | 7 | ZV | 1 | 1 | 0 | 1.062 | 0 | 967 | 100 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 |
| 8 | Bus | 8 | TV | 1 | 1 | 0 | 1.09 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9 | Bus | 9 | LV | 1 | 1 | 0 | 1.056 | 0 | 1767 | 100 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 |
| 10 | Bus | 10 | LV | 1 | 1 | 0 | 1.051 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 11 | Bus | 11 | LV | 1 | 1 | 0 | 1.057 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| BRANCH DATA FOLLOWS | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| FROM | TO | LOAD FLOW AREA | LOSS ZONE | CIRCUIT | TYPE | R | X | B | LINE MVA RATING 1 | LINE MVA RATING 2 | LINE MVA RATING 3 | CONTROL BUS | SIDE | XFR FINAL TURN RATIO | XFR FINAL ANGLE | MIN TAP.PHASE SHIFT | MAX TAP/PHASE SHIFT | STEP SIZE | MIN VOLT/MVAR MW LIMIT | MAX VOLT/MVAR MW LIMIT |
| 1 | 5 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 11 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 10 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 6 | 1 | 1 | 1 | 0 | 0.0025 | 0.025 | 0.04375 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 7 | 1 | 1 | 1 | 0 | 0.001 | 0.01 | 0.0175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 8 | 1 | 1 | 1 | 0 | 0.00367 | 0.0367 | 0.5775 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 9 | 1 | 1 | 1 | 0 | 0.0055 | 0.055 | 0.385 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 10 | 1 | 1 | 1 | 0 | 0.001 | 0.01 | 0.0175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 11 | 1 | 1 | 1 | 0 | 0.0025 | 0.025 | 0.04375 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Problem C:

# Problem B:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| BUS DATA FOLLOWS | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| BUS | | | | LOAD FLOW AREA | LOSS ZONE | TYPE | V\_MAG | V\_ANG | LOAD\_MW | LOAD\_MVA | G\_MW | G\_MVAR | BASE\_KV | V\_DESIRED | MAX MVAR/VOLT LIMIT | MIN MVAR/VOLT LIMIT | SHUNT\_G | SHUNT\_B | REMOTE CONTROLLED BUS |
| 1 | Bus | 1 | HV | 1 | 1 | 3 | 1.06 | 20.2 | 0 | 0 | 700 | 185 | 0 | 1.03 | 0 | 0 | 0 | 0 | 0 |
| 2 | Bus | 2 | HV | 1 | 1 | 2 | 1.045 | 0 | -700 | -28.37 | 0 | 0 | 0 | 1.01 | 0 | 0 | 0 | 0 | 0 |
| 3 | Bus | 3 | HV | 1 | 1 | 2 | 1.01 | 0 | -719 | -131.883 | 0 | 0 | 0 | 1.03 | 0 | 0 | 0 | 0 | 0 |
| 4 | Bus | 4 | HV | 1 | 1 | 2 | 1.019 | 0 | -700 | -95.8365 | 0 | 0 | 0 | 1.01 | 0 | 0 | 0 | 0 | 0 |
| 5 | Bus | 5 | HV | 1 | 1 | 0 | 1.02 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 6 | Bus | 6 | LV | 1 | 1 | 0 | 1.07 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | Bus | 7 | ZV | 1 | 1 | 0 | 1.062 | 0 | 967 | 100 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 |
| 8 | Bus | 8 | TV | 1 | 1 | 0 | 1.09 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9 | Bus | 9 | LV | 1 | 1 | 0 | 1.056 | 0 | 1767 | 100 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 |
| 10 | Bus | 10 | LV | 1 | 1 | 0 | 1.051 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 11 | Bus | 11 | LV | 1 | 1 | 0 | 1.057 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| BRANCH DATA FOLLOWS | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| FROM | TO | LOAD FLOW AREA | LOSS ZONE | CIRCUIT | TYPE | R | X | B | LINE MVA RATING 1 | LINE MVA RATING 2 | LINE MVA RATING 3 | CONTROL BUS | SIDE | XFR FINAL TURN RATIO | XFR FINAL ANGLE | MIN TAP.PHASE SHIFT | MAX TAP/PHASE SHIFT | STEP SIZE | MIN VOLT/MVAR MW LIMIT | MAX VOLT/MVAR MW LIMIT |
| 1 | 5 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 11 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 10 | 1 | 1 | 1 | 0 | 0 | 0.0167 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 6 | 1 | 1 | 1 | 0 | 0.0025 | 0.025 | 0.04375 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 7 | 1 | 1 | 1 | 0 | 0.001 | 0.01 | 0.0175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 8 | 1 | 1 | 1 | 0 | 0.00367 | 0.0367 | 0.5775 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 9 | 1 | 1 | 1 | 0 | 0.0055 | 0.055 | 0.385 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 10 | 1 | 1 | 1 | 0 | 0.001 | 0.01 | 0.0175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 11 | 1 | 1 | 1 | 0 | 0.0025 | 0.025 | 0.04375 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |