Submitted by B1 Group 2

Project Presentation

Thirteen Bus System

EEE 306 Sessional

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Objectives:

a Performing load flow analysis on a 13-bus power system

b Increasing voltage of load buses

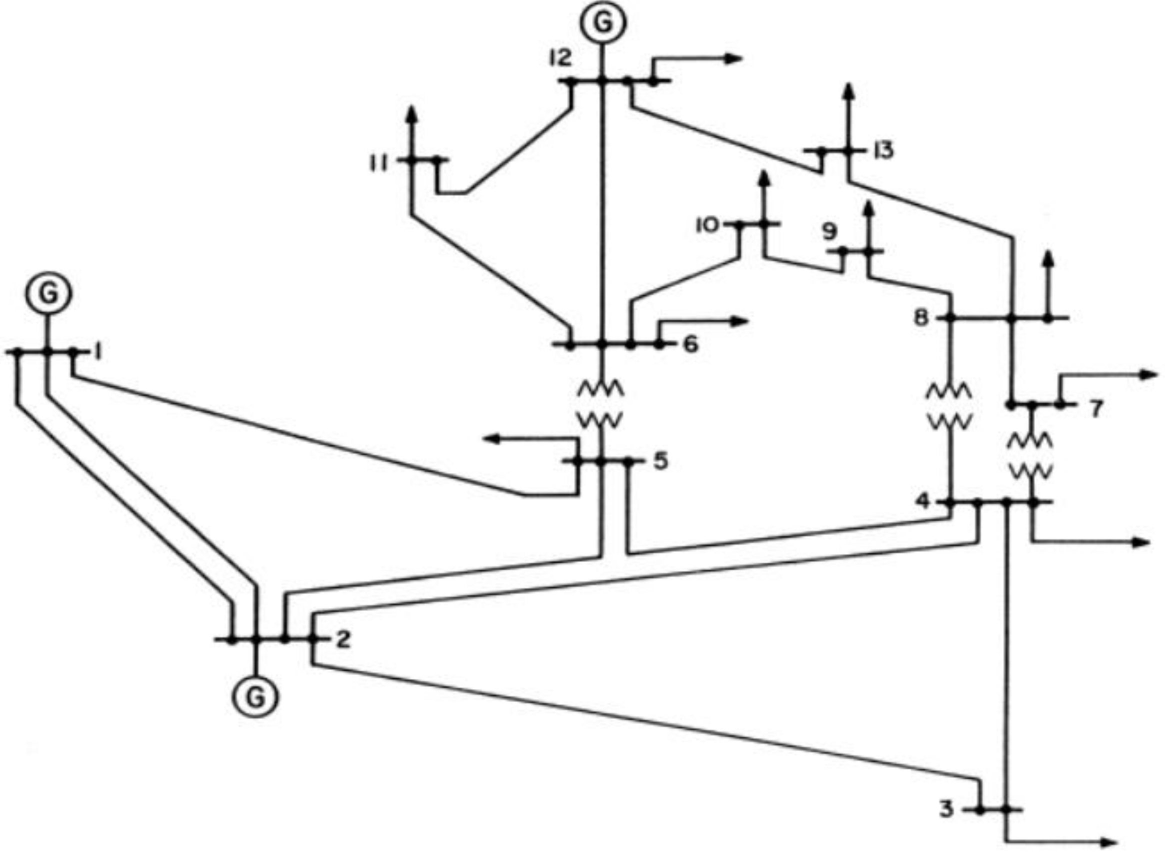
c Determining the rating of circuit breaker through fault analysis

d Reducing three phase fault current at load buses

Platforms:

- CYME PSAF
- MATLAB

The Given Power System:



Assumptions

- Generator Rating : 100 MVA
- Transformer Rating : 100 MVA
- Transformer Standard : 100 MVA
- Emergency Rating : 150MVA
- Transformer X1/R1 : 999.99
- Z = X
- Branch Data: Loading Limit 700 A, Emergency Loading Limit 750 A
- Generator Data : G1 → 1.06 * 138 = 146.28 kV
- Generator Data : G2 → 1.02 * 138 = 140.76 kV
- Generator Data : G12 → 1.01 * 66 = 66.66 kV
- Bus Data: Bus 7 → PF = 0.9 Lagging

Bus Data:

Bus No.	Nominal Voltage (kV)	Type	Real Power Load (MW)	Reactive Power Load (MVAR)
1	138	Slack Bus	--	--
2	138	PV	--	--
3	138	PQ	95	20
4	138	PQ	45	0
5	138	PQ	10	2
6	66	PQ	11	7.5
7	66	PQ	K×L [1]	--- [2]
8	66	PQ	25	7
9	66	PQ	20	6
10	66	PQ	20	5
11	66	PQ	30	10
12	66	None	13.5	6
13	66	PQ	20	5

Replace ‘L’ with your group number. **K = 4 for group A2 and K=5 for group B1.**

Load power factor at bus 7 should be maintained at 0.9 lagging.

Generator Data:

(2) Generator Data

Bus No.	Pg	Vg (pu)	Q_{max} (MVAR)	Q_{min} (MVAR)
1	Slack (not specified)	1.06	-	-
2	100	1.02	50	-40
12	20	1.01	100	-60

Branch Data:

From	To	R (pu)	X (pu)	B (pu)
Bus 1	Bus 2	0.01938	0.05917	0.05280
Bus 1	Bus 5	0.05403	0.22304	0.04920
Bus 2	Bus 3	0.04699	0.19797	0.04380
Bus 2	Bus 4	0.05811	0.17632	0.03400
Bus 2	Bus 5	0.05695	0.17388	0.03460
Bus 3	Bus 4	0.06701	0.17103	0.01280
Bus 4	Bus 5	0.01335	0.04211	0
Bus 6	Bus 10	0.09498	0.19890	0
Bus 6	Bus 11	0.12291	0.25581	0
Bus 6	Bus 12	0.06615	0.13027	0
Bus 7	Bus 8	0	0.11001	0
Bus 8	Bus 9	0.03181	0.08450	0
Bus 8	Bus 13	0.12711	0.27038	0
Bus 9	Bus 10	0.08205	0.19207	0
Bus 11	Bus 12	0.22092	0.19988	0
Bus 12	Bus 13	0.17093	0.34802	0

Transformer Data:

From	To	R (pu)	X (pu)	B (pu)
Bus 4	Bus 7	0	0.20912	0
Bus 4	Bus 8	0	0.55618	0
Bus 5	Bus 6	0	0.25202	0

Objective A

Part 1: Load flow analysis on PSAF

Bus Voltage Report

ID	Zone	kV Base	V Sol [pu]	Ang sol[deg]	Vmin(pu)	Vmax(pu)	Pgen(MW)	Q gen (MVAR)	P Load(MW)	Q Load(MVAR)
B1	0	138	1.06	0	0.9	1.1	193.5	168.91	0	0
B10	0	66	0.942	-15.1	0.9	1.1	0	0	20	5
B11	0	66	0.937	-16.5	0.9	1.1	0	0	30	10
B12	0	66	1.01	-13.8	0.9	1.1	20	38.55	13.5	6
B13	0	66	0.917	-17	0.9	1.1	0	0	20	5
B2	0	138	1.02	-0.2	0.9	1.1	100	-115.63	0	0
B3	0	138	0.957	-7.8	0.9	1.1	0	0	95	20
B4	0	138	0.99	-5.3	0.9	1.1	0	0	45	0
B5	0	138	1.016	-3.4	0.9	1.1	0	0	10	2
B6	0	66	0.986	-12.8	0.9	1.1	0	0	11	7.5
B7	0	66	0.968	-10.6	0.9	1.1	0	0	10	4.84
B8	0	66	0.936	-14.3	0.9	1.1	0	0	25	7
B9	0	66	0.929	-15.2	0.9	1.1	0	0	20	6

Generator Report:

ID	Bus ID	Dbase ID	Type	Rated S (MVA)	kV Nominal	Generator Type	P (MW)	Q (MVAR)	S (MVA)	P Factor (%)	I (pu)	Qmin (MVAR)	Q Max (MVAR)	Ctrled BusID	Ctrled Bus/V (pu)
G12		B12	G12	Generator	100	66.66	PV	20	38.55	43.43	46.1	0.43	100	-60	B12
G1		B1	G1	Generator	100	146.28	SW	193.5	168.91	256.85	75.3	2.423	43.59	-43.59	B1
G2		B2	G2	Generator	100	140.08	PV	100	-115.63	152.88	65.4	1.499	50	-40	B2

Line Report:

ID	Bus From	Bus To	Dbase ID	Type	kV Nominal	Length	P (MW)	Q (MVAR)	S(MVA)	P.Factor (%)	I (pu)	I angle (deg)	P Losses (MW)	Q Losses (MVAR)	Ampacity (Norm.) (pu)	Loading (%)	Ampacity(Emer) (pu)	Loading Emer (%)
L610	B6	B10	L610	Line	66	1	23.78	11.27	26.31	90.4	0.267	-38.2	0.68	1.42	0.8	33.3	0.857	31.1
L611	B6	B11	L611	Line	66	1	26.47	7.16	27.42	96.5	0.278	-27.9	0.95	1.98	0.8	34.7	0.857	32.4
L612	B6	B12	L612	Line	66	1	3.88	-19.72	20.1	19.3	0.204	66.1	0.27	0.54	0.8	25.5	0.857	23.8
L813	B8	B13	L813	Line	66	1	14.98	-0.28	14.98	100	0.16	-13.2	0.33	0.69	0.8	20	0.857	18.7
L910	B9	B10	L910	Line	66	1	-3.07	-4.78	5.68	-54	0.061	107.5	0.03	0.07	0.8	7.6	0.857	7.1
L12s	B1	B2	L12	Line	138	1	27.15	59.81	65.69	41.3	0.62	-65.6	0.81	-3.25	1.673	37	1.793	34.6
L12	B1	B2	L12	Line	138	1	27.15	59.81	65.69	41.3	0.62	-65.6	0.81	-3.25	1.673	37	1.793	34.6
L23	B2	B3	L23	Line	138	1	70.2	18.06	72.48	96.8	0.711	-14.6	2.41	5.88	1.673	42.5	1.793	39.6
L24	B2	B4	L24	Line	138	1	51.77	1.02	51.78	100	0.508	-1.3	1.5	1.12	1.673	30.3	1.793	28.3
L34	B3	B4	L34	Line	138	1	-27.22	-7.82	28.32	-96.1	0.296	156.1	0.58	0.27	1.673	17.7	1.793	16.5
L15	B1	B5	L15	Line	138	1	139.19	49.29	147.66	94.3	1.393	-19.5	2.55	-12.68	1.673	83.3	1.793	77.7
L25	B2	B5	L25	Line	138	1	30.72	-8.6	31.91	96.3	0.313	15.4	0.54	-1.93	1.673	18.7	1.793	17.4
L45	B4	B5	L45	Line	138	1	-90.44	-32.04	95.95	-94.3	0.97	155.2	1.26	3.96	1.673	57.9	1.793	54.1
L78	B7	B8	L910	Line	66	1	31.96	3.35	32.13	99.5	0.332	-16.5	0.9	2.12	0.8	41.5	0.857	38.7
L89	B8	B9	L89	Line	66	1	17.04	1.5	17.1	99.6	0.183	-19.3	0.11	0.28	0.8	22.8	0.857	21.3
L1112	B11	B12	L1112	Line	66	1	-4.48	-4.81	6.58	-68.2	0.07	116.5	0.11	0.59	0.8	8.8	0.857	8.2
L1213	B12	B13	L1213	Line	66	1	5.52	6.89	8.83	62.5	0.087	-65.1	0.17	0.92	0.8	10.9	0.857	10.2

Assumptions:

Loading Limit: 700A

Emergency Loading Limit: 750A

Abnormal Report: part 1

BUSES OUTSIDE VOLTAGE LIMITS (100 %)

Bus ID	Zone	kV Base	Vmin - [pu]	Vmax - [pu]	V sol - [pu]	Ang sol - [deg]

OVERLOADED LINES & CABLES (WITHIN 100 %)

ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]	Emergency Loading Limit - [pu]

UNDERLOADED LINES & CABLES (WITHIN 50 %)

ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]
L610	B6	B10	0.267	0.4
L611	B6	B11	0.278	0.4
L612	B6	B12	0.204	0.4
L813	B8	B13	0.16	0.4
L910	B9	B10	0.061	0.4
L12s	B1	B2	0.62	0.837
L12	B1	B2	0.62	0.837
L23	B2	B3	0.711	0.837
L24	B2	B4	0.508	0.837
L34	B3	B4	0.296	0.837
L25	B2	B5	0.313	0.837
L78	B7	B8	0.332	0.4
L89	B8	B9	0.183	0.4
L1112	B11	B12	0.07	0.4
L1213	B12	B13	0.087	0.4

Abnormal Report: part 2

OVERLOADED TRANSFORMERS (WITHIN 100 %)								
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]			
UNDERLOADED TRANSFORMERS (WITHIN 50 %)								
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]				
T47	B4	B7	43.716	50				
T48	B4	B8	28.424	50				
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)								
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]			
G2	B2	100	-115.63	-40	50			
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)								
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]			

Summery Report:

LOAD FLOW STUDY PARAMETERS	
Study :	ModelGrid1
Time :	Tue Feb 28 10h08m54s 2023
Method :	Newton-Raphson
Constraints :	Not applied
Flat start :	Yes
Tcul txfo used as fixed tap :	n\a
Block Q-flow Txfo Adjustment	n\a
Block P-flow Txfo Adjustment :	n\a
Block Switchable Shunt Adjustment :	n\a
Block DC Link Adjustment :	n\a
Base power :	100.00 [MVA]
Tolerance :	0.100 [MVA]

COMPLETE SUMMARY REPORT

Summary Data	**Active Power**	**Reactive Power**
Total generation	**313.495**	**91.826**
Spinning reserve	-43.495	
Static Load	299.500	73.343
Shunt loads	0.000	0.000
Motor loads	0.000	0.000
Total load	**299.500**	**73.343**
Line / cable losses	13.995	-1.272
Transformer losses	0.000	19.755
Total losses	**13.995**	**18.483**
Mismatches	0.000	0.000

Objective a

Part 2: Load flow analysis on MATLAB

Flow chart for Newton-Raphson

Taking Bus Data
13 x 10 Matrix

Taking Line Data
13 x 10 Matrix

Create Admittance Matrix

Extract Power Data from Power Data Matrix

Calculating Scheduled Power As Net Power

Calculating PV and PQ Buses

Calculate PQ Mismatch Matrix

Create Jacobian Matrix

Solve Equations

Update Voltage Magnitude for PQ and PV Buses until tolerance requirement (while loop)

Calculate the Required Data

$$P_i = |V_i|^2 G_{ii} + \sum_{\substack{n=1 \\ n \neq i}}^{N} |V_i V_n Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i)$$

$$Q_i = -|V_i|^2 B_{ii} - \sum_{\substack{n=1 \\ n \neq i}}^{N} |V_i V_n Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i)$$

$$\Delta P_i = P_{i,\text{sch}} - P_{i,\text{calc}}$$

$$\Delta Q_i = Q_{i,\text{sch}} - Q_{i,\text{calc}}$$

```
    %calculation of P-Q mismatch matrix
    for i = 1:nbus
        for k = 1:nbus
            P(i) = P(i) + V(i)* V(k)*(abs(Y(i,k))*cos(Yangle(i,k)+del(k)-del(i)));
            Q(i) = Q(i) - V(i)* V(k)*(abs(Y(i,k))*sin(Yangle(i,k)+del(k)-del(i)));
        end
    end
    for i=1:nbus
        if type(i)==2 || type(i)==4
            if Q(i)<=Qmin(i)
               type(i)=4;
               Qsch(i)=Qmin(i);
            elseif Q(i)>=Qmax(i)
               type(i)=4;
               Qsch(i)=Qmax(i);
            else
               type(i)=2;
            end
        end
    end

PV = find(type == 2 | type == 1);
PQ = find(type == 3 | type == 4);
n_PV = length(PV);
n_PQ = length(PQ);

    dPa = Psch-P;
    dQa = Qsch-Q;
    k = 1;
    dQ = zeros(n_PQ,1);
```

$$\frac{\partial P_i}{\partial \delta_j} = -|V_i V_j Y_{ij}| \sin(\theta_{ij} + \delta_j - \delta_i)$$

$$\frac{\partial P_i}{\partial \delta_i} = -Q_i - |V_i|^2 B_{ii}$$

$$|V_j| \frac{\partial P_i}{\partial |V_j|} = |V_j|\ |V_i Y_{ij}| \cos(\theta_{ij} + \delta_j - \delta_i)$$

$$|V_i| \frac{\partial P_i}{\partial |V_i|} = \frac{\partial Q_i}{\partial \delta_i} + 2|V_i|^2 G_{ii} = P_i + |V_i|^2 G_{ii}$$

```
% Calculate J11
for i = 1:(nbus-1)
    m = i+1;
    for k = 1:(nbus-1)
        n_PV = k+1;
        if n_PV == m
            J11(i,k) = -Q(m)- V(m)^2*B(m,m);
        else
            J11(i,k) = -abs(V(m))* abs(V(n_PV))*abs(Y(m,n_PV))*sin(Yangle(m,n_PV)+del(n_PV)-del(m));
        end
    end
end

% Calculate J12
for i = 1:(nbus-1)
    m = i+1;
    for k = 1:n_PQ
        n_PV = PQ(k);
        if n_PV == m
            J12(i,k) = P(m)+V(m)^2*G(m,m);
        else
            J12(i,k) = abs(V(m))*abs(V(n_PV))*abs(Y(m,n_PV))*cos(Yangle(m,n_PV)+del(n_PV)-del(m));
        end
    end
end
```

$$\frac{\partial Q_i}{\partial \delta_j} = -|V_i V_j Y_{ij}|\cos(\theta_{ij} + \delta_j - \delta_i)$$

$$\frac{\partial Q_i}{\partial \delta_i} = P_i - |V_i|^2 G_{ii}$$

$$|V_j|\frac{\partial Q_i}{\partial |V_j|} = -|V_j|\,|V_i Y_{ij}|\sin(\theta_{ij} + \delta_j - \delta_i) = \frac{\partial P_i}{\partial \delta_j}$$

$$|V_i|\frac{\partial Q_i}{\partial |V_i|} = -\frac{\partial P_i}{\partial \delta_i} - 2|V_i|^2 B_{ii} = Q_i - |V_i|^2 B_{ii}$$

```
% Calculate J21
for i = 1:n_PQ
    m = PQ(i);
    for k = 1:(nbus-1)
        n_PV = k+1;
        if n_PV == m
            J21(i,k) = P(m)-(V(m)^2)* G(m,m);
        else
            J21(i,k) = -(abs(V(m))* abs(V(n_PV))*abs(Y(m,n_PV))*(cos(Yangle(m,n_PV)+del(n_PV)-del(m)));
        end
    end
end

% Calculate J22
for i = 1:n_PQ
    m = PQ(i);
    for k = 1:n_PQ
        n_PV = PQ(k);
        if n_PV == m
            J22(i,k) = Q(m)-V(m)^2*B(m,m);
        else
            J22(i,k) = -abs(V(m))*abs(V(n_PV))*abs(Y(m,n_PV))*sin(Yangle(m,n_PV)+del(n_PV)-del(m));
        end
    end
end
```

$$\underbrace{\left[\begin{array}{ccc|ccc} \frac{\partial P_2}{\partial \delta_2} & \cdots & \frac{\partial P_2}{\partial \delta_4} & |V_2|\frac{\partial P_2}{\partial |V_2|} & \cdots & |V_4|\frac{\partial P_2}{\partial |V_4|} \\ \vdots & \mathbf{J}_{11} & \vdots & \vdots & \mathbf{J}_{12} & \vdots \\ \frac{\partial P_4}{\partial \delta_2} & \cdots & \frac{\partial P_4}{\partial \delta_4} & |V_2|\frac{\partial P_4}{\partial |V_2|} & \cdots & |V_4|\frac{\partial P_4}{\partial |V_4|} \\ \hline \frac{\partial Q_2}{\partial \delta_2} & \cdots & \frac{\partial Q_2}{\partial \delta_4} & |V_2|\frac{\partial Q_2}{\partial |V_2|} & \cdots & |V_4|\frac{\partial Q_2}{\partial |V_4|} \\ \vdots & \mathbf{J}_{21} & \vdots & \vdots & \mathbf{J}_{22} & \vdots \\ \frac{\partial Q_4}{\partial \delta_2} & \cdots & \frac{\partial Q_4}{\partial \delta_4} & |V_2|\frac{\partial Q_4}{\partial |V_2|} & \cdots & |V_4|\frac{\partial Q_4}{\partial |V_4|} \end{array}\right]}_{\text{Jacobian}} \underbrace{\left[\begin{array}{c} \Delta\delta_2 \\ \vdots \\ \Delta\delta_4 \\ \hline \frac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta|V_4|}{|V_4|} \end{array}\right]}_{\text{Corrections}} = \underbrace{\left[\begin{array}{c} \Delta P_2 \\ \vdots \\ \Delta P_4 \\ \hline \Delta Q_2 \\ \vdots \\ \Delta Q_4 \end{array}\right]}_{\text{Mismatches}}$$

```
% Form Jacobian matrix
J(1:nbus-1,1:nbus-1) = J11;
J(1:nbus-1,nbus:end) = J12;
J(nbus:end,1:nbus-1) = J21;
J(nbus:end,nbus:end) = J22;

% Solve equations
correction_matrix = J\M;
del_theta = correction_matrix(1:nbus-1);
delV = correction_matrix(nbus:end);

    %% updating
    % Updating voltage angles
  del(2:end) = del(2:end) + del_theta;

% Updating voltage magnitudes for PQ and PV buses
  pv_pq_idx = find(type == 3 | type == 4); % indices of PV and PQ buses
  V(pv_pq_idx) = V(pv_pq_idx) + delV;

% Incrementing iteration counter
  iteration = iteration + 1;

% Computing tolerance as maximum absolute value of correction vector
   tolerance = max(abs([del_theta; delV]));

end
Del = 180/pi*del;


[fb, tb, Pij, Qij] = loadanalysis(Y,bus_data,line_data,V,del,base,iteration);
```

Analysis on MATLAB

Newton Raphson Loadflow Analysis

busNum	voltage	angle	genMW	genMVar	loadMW	loadMVar
1	1.06	0	197.42	56.246	0	0
2	1.02	-3.3084	100	9.1034	0	0
3	0.94287	-12.124	1.5939e-05	7.6529e-05	95	20
4	0.96685	-10.495	-1.1119e-05	-4.2043e-05	45	0
5	0.98371	-9.1761	-2.657e-06	-9.3001e-06	10	2
6	0.98375	-9.186	-6.2848e-06	-1.436e-05	11	7.5
7	0.96684	-10.496	-8.3332e-08	3.6609e-06	10	4.8432
8	0.96679	-10.514	-8.2934e-06	-1.4235e-05	25	7
9	0.95432	-11.425	6.8075e-06	1.9708e-05	20	6
10	0.9535	-11.377	5.1429e-06	1.1942e-05	20	5
11	0.96006	-11.816	3.3195e-06	4.7956e-06	30	10
12	1.01	-11.557	20	54.941	13.5	6
13	0.96217	-12.587	1.0426e-06	2.541e-06	20	5

Total	17.919	46.947	317.419	120.290	299.500	73.343

****

Line Flow and Losses

From Bus	To Bus	P MW	Q MVar	From Bus	To Bus	P MW	Q MVar	Line Loss MW	Line Loss MVar
1	2	117.33	33.31	2	1	-114.73	-31.08	2.60	2.23
1	5	80.09	20.07	5	1	-76.75	-11.45	3.33	8.62
2	3	80.70	24.05	3	2	-77.45	-14.56	3.25	9.49
2	4	73.56	9.13	4	2	-70.47	-3.12	3.09	6.01
2	5	60.47	2.71	5	2	-58.46	-0.03	2.01	2.67
3	4	-17.55	-6.70	4	3	17.81	6.19	0.26	-0.50

4	5	-58.22	-19.67	5	4	58.76	21.37	0.54	1.70
6	10	20.64	5.45	10	6	-20.19	-4.51	0.45	0.94
6	11	17.47	1.11	11	6	-17.08	-0.30	0.39	0.81
6	12	17.34	-27.98	12	6	-16.60	29.44	0.74	1.46
7	8	0.26	0.04	8	7	-0.26	-0.04	0.00	0.00
8	9	19.96	6.89	9	8	-19.81	-6.49	0.15	0.40
8	13	10.92	-3.26	13	8	-10.74	3.63	0.18	0.38
9	10	-0.19	0.49	10	9	0.19	-0.49	0.00	0.00
11	12	-12.92	-9.70	12	11	13.54	10.27	0.63	0.57
12	13	9.56	9.23	13	12	-9.26	-8.63	0.30	0.60
4	7	10.26	4.89	7	4	-10.26	-4.89	0.00	0.00
4	8	55.62	10.61	8	4	-55.62	-10.59	0.00	0.02
5	6	66.45	-13.91	6	5	-66.45	13.92	0.00	0.01
Total Loss								17.919	35.406

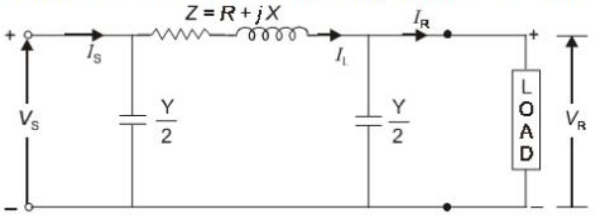
```
****************************************************************************
****
 The number of Iterations it took:6
>>
```

Objective b

Increasing voltage of load buses

Medium Transmission Line:

Medium Transmission line (>80 km <250 km)



Medium length line, nominal π representation.

From KCL, the current in the series impedance designated by I_L is

$$I_L = I_R + \frac{Y}{2} V_R \qquad (13)$$

From KVL, the sending end voltage is

$$V_S = V_R + Z I_L \qquad (14)$$

From equations 14 and 13

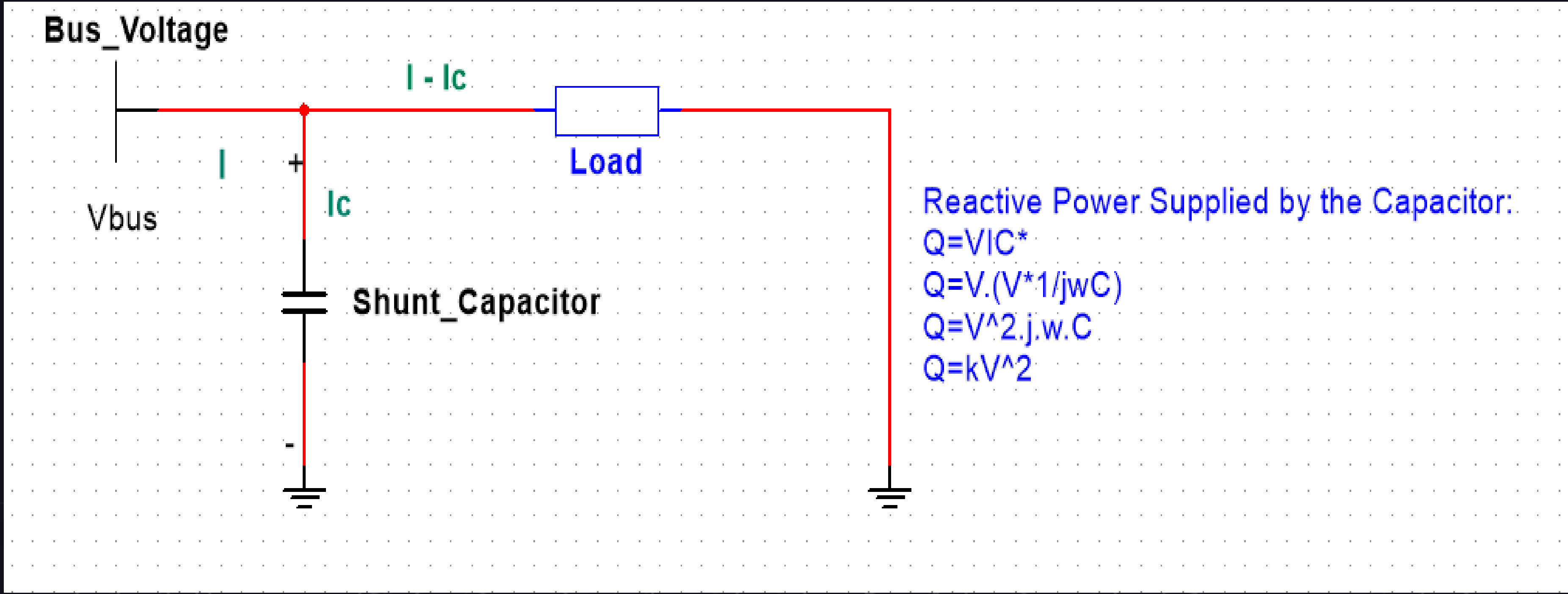
$$V_S = \left(1 + \frac{ZY}{2}\right) V_R + Z I_R \qquad (15)$$

The sending end current is,

$$I_S = I_L + \frac{Y}{2} V_S \qquad (16)$$

Here, due to shunt capacitance
VR becomes greater than Vs at no load.

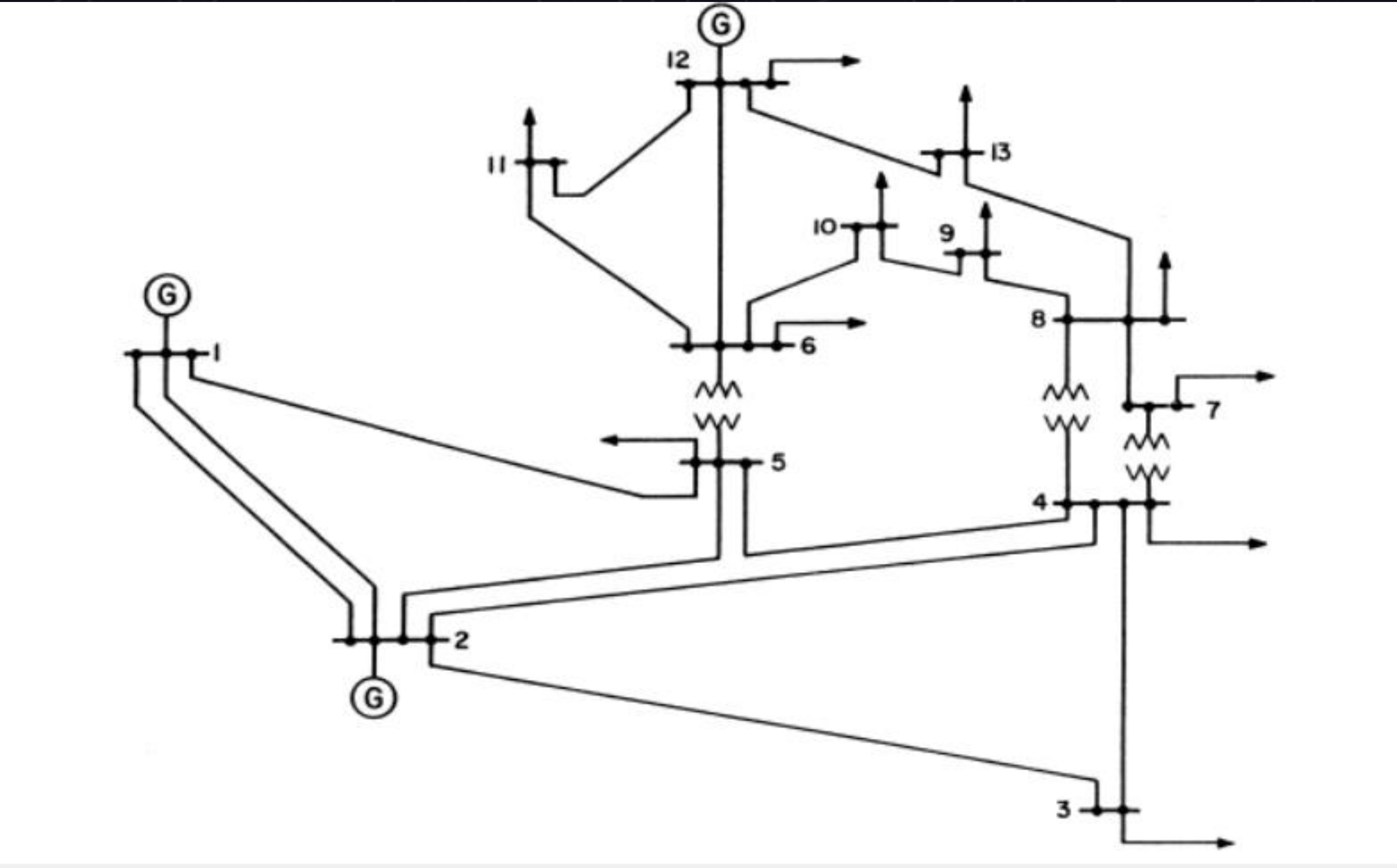
Load Bus Voltage increasing using Shunt Capacitor:



Effect of shunt capacitor on load bus voltage :

Bus ID	Before Voltage pu	Required Voltage (pu)	1st trial	2nd trial	3rd trial	4th trial	5th trial	Final Voltage	Capacitance MVAR	% rise
B10	0.942	0.96084	1	0.969	0.966	0.96	0.959	0.962	5	2.123142
B11	0.937	0.95574	0.987	0.961	0.96	0.958	0.958	0.958	2.5	2.241195
B13	0.917	0.93534	1.006	0.96	0.947	0.94	0.939	0.935	0	1.962923
B3	0.957	0.97614	0.981	0.968	0.968	0.967	0.967	0.976	8	1.985371
B4	0.99	1.0098	1.017	1.002	1.003	1.001	1.001	1.01	15	2.020202
B5	1.016	1.03632	1.035	1.024	1.025	1.024	1.024	1.035	45	1.870079
B6	0.986	1.00572	1.018	1.001	1.001	0.999	0.999	1.004	10	1.825558
B7	0.968	0.98736	1.031	0.998	0.994	0.986	0.986	0.988	0	2.066116
B8	0.936	0.95472	1.014	0.973	0.966	0.957	0.956	0.956	0	2.136752
B9	0.929	0.94758	1.008	0.966	0.96	0.951	0.949	0.949	0	2.152853

Let's Look at The Given Power System again:



Shunt Capacitance Table:

	ID	Bus ID	DBase ID	Duplic	Status	MVAR	kV Nominal
1	C10	B10	C10	1	☑	5.000	138.000
2	C11	B11	C11	1	☑	2.500	66.000
3	C13	B13	C13	1	☐	0.800	66.000
4	C3	B3	C3	1	☑	8.000	138.000
5	C4	B4	C4	1	☑	15.000	138.000
6	C5	B5	C5	1	☑	45.000	138.000
7	C6	B6	C6	1	☑	10.000	66.000
8	C7	B7	C7	1	☐	1.000	66.000
9	C8	B8	C8	1	☐	0.000	66.000
10	C9	B9	C9	1	☐	0.000	66.000

Reason for using shunt capacitor:

- ❖Improves power factor
- ❖Eases the lag between current and voltage
- ❖Improves power stability
- ❖Improves voltage profile

Objective C

Determining the rating of circuit breakers through fault analysis

138 kV Circuit Breaker

Relevant Formaula:

$$Voltage\ Range\ Factor, K = 1.6$$

$$Lower\ Limit\ of\ Operating\ Voltage = \frac{Rated\ Maximum\ Voltage}{K}$$

$$Maximum\ Symmetrical\ Interrupting\ Current = K \times Rated\ Short\ Circuit\ Current$$

$$Rated\ Voltage = Rated\ Maximum\ Voltage$$

$$Rated\ Momentary\ Current = Maximum\ Symmetrical\ Interrupting\ Current$$

Selection Criteria for Circuit Breakers based current profiles:

- The maximum instantaneous current which the breaker must carry
- The total current when the breakers contacts part to interrupt the circuit

Significance of K = 1.6

- Instantaneous current following a fault has a DC component;
- K determines the range of Voltage over which rated short circuit current * operating voltage product is constant.
- 1.6 chosen following the standard values for high voltage industrial applications

Circuit Breaker Rating:

Bus No.	Related Maximum Voltage (kV)	Rated Voltage (kV)	Lower Limit of Operating Voltage (kV)	Fault Type	Short Circuit Current (A)	Momentary Current(A)	Maximum Symmetrical Interrupting Capability(A)
B1	138	138	86.25	LLL	5779.7679	9247.62864	9247.62864
B2	138	138	86.25	LLL	5719.822	9151.7152	9151.7152
B3	138	138	86.25	LLL	2420.3317	3872.53072	3872.53072
B4	138	138	86.25	LLL	4023.8454	6438.15264	6438.15264
B5	138	138	86.25	LLL	4678.2311	7485.16976	7485.16976
B6	66	66	41.25	LLL	6017.2706	9627.63296	9627.63296
B7	66	66	41.25	LLL	3934.2966	6294.87456	6294.87456
B8	66	66	41.25	LLL	4239.3098	6782.89568	6782.89568
B9	66	66	41.25	LLL	3615.3839	5784.61424	5784.61424
B10	66	66	41.25	LLL	3511.6684	5618.66944	5618.66944
B11	66	66	41.25	LLL	2482.4208	3971.87328	3971.87328
B12	66	66	41.25	LLL	8094.2353	12950.77648	12950.77648
B13	66	66	41.25	LLL	3126.1445	5001.8312	5001.8312

Objective d

Reducing three phase fault current at load buses

Reduction of Fault Current :

Fault Current Decreasing Analysis						
Bus	Fault	Want Value	First(14,999,40,40)	2nd(30,40,40,99)	3rd	4th(WITH LINE LENGTH CHANGED)
B10	3511.6684	3406.318348	3405	3379	3401	3407
B11	2482.4208	2407.948176	2441	2431	2235	2421
B13	3126.1445	3032.360165	3062	3048	3069	3047
B3	2420.3317	2347.721749	1746	1732	1802	2305
B4	4023.8454	3903.130038	3533	3445	3572	3848
B5	4678.2311	4537.884167	3819	3643	3882	4100
B6	6017.2706	5836.752482	5751	5687	5720	5794
B7	3934.2966	3816.267702	3737	3697	3753	3792
B8	4239.3098	4112.130506	4055	4016	4069	4099
B9	3615.3839	3506.922383	3487	3459	3495	3505

	% Reduction	With Series Reactor	without line changed	changed line length
B10	3.037541927	3.777930741	3.151447899	2.980588942
B11	1.668564814	2.071397404	9.966916165	2.474229994
B13	2.051872522	2.499708507	1.82795453	2.531696791
B3	27.86112746	28.43956058	25.54739501	4.765119591
B4	12.19841597	14.38537872	11.22919385	4.370083403
B5	18.36658091	22.12868663	17.01991806	12.36003711
B6	4.425105961	5.488711111	4.940289705	3.710496251
B7	5.014787141	6.031487306	4.608107076	3.616824415
B8	4.347636967	5.267598042	4.01739453	3.309732164
B9	3.551044745	4.325512984	3.329768106	3.053172306

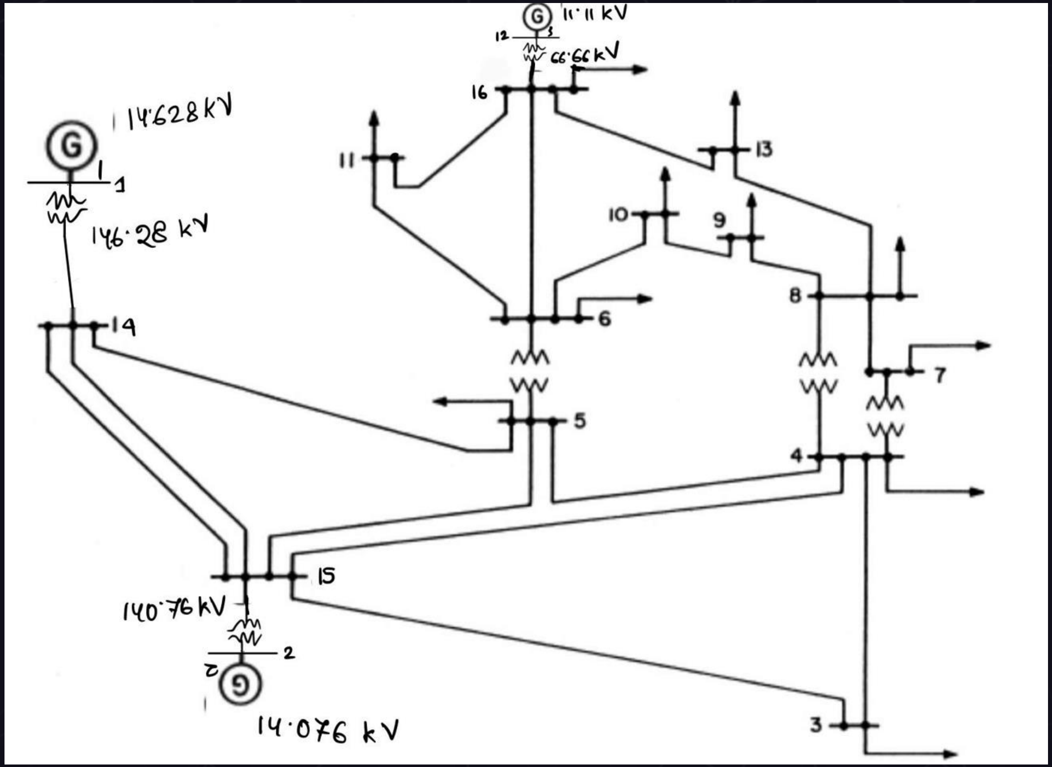
Series Reactor Table:

	ID	Bus From	Bus To	DBase ID	Duplic	Status
1	SR1211	B12_2	B11_2	SR1211	1	☑
2	SR1213	B12_2	B13_2	SR1213	1	☐
3	SR15	B1_2	B5_2	SR15	1	☑
4	SR23	B2_2	B3_2	SR23	1	☑
5						

Line Length Change

	ID	Bus From	Bus To	DBase ID	Duplic	Status	Series X Compensation	Length
1	L1111_	B11	B11_2	L1112	1	☑	0.00	0.5000
2	L1112	B11	B12	L1112	1	☐	0.00	1.0000
3	L11_	B1	B1_2	L15	1	☑	0.00	0.5000
4	L12	B1	B2	L12	1	☑	0.00	1.0000
5	L1212_	B12	B12_2	L1112	1	☑	0.00	0.5000
6	L1213	B12	B13	L1213	1	☑	0.00	1.0300
7	L12s	B1	B2	L12	1	☑	0.00	1.0000
8	L1313_	B13	B13_2	L1213	1	☐	0.00	1.0000
9	L15	B1	B5	L15	1	☐	0.00	1.0000
10	L22_	B2	B2_2	L23	1	☑	0.00	0.4000
11	L23	B2	B3	L23	1	☐	0.00	1.0000
12	L24	B2	B4	L24	1	☑	0.00	0.8000
13	L25	B2	B5	L25	1	☑	0.00	1.0000
14	L33_	B3	B3_2	L23	1	☑	0.00	0.5000
15	L34	B3	B4	L34	1	☑	0.00	0.7000
16	L45	B4	B5	L45	1	☑	0.00	0.8000
17	L55_	B5_2	B5	L15	1	☑	0.00	1.0000
18	L610	B6	B10	L610	1	☑	0.00	1.0000
19	L611	B6	B11	L611	1	☑	0.00	0.9250
20	L612	B6	B12	L612	1	☑	0.00	1.0000
21	L78	B7	B8	L78	1	☑	0.00	1.0000
22	L813	B8	B13	L813	1	☑	0.00	1.0000
23	L89	B8	B9	L89	1	☑	0.00	1.0000
24	L910	B9	B10	L910	1	☑	0.00	1.2000

Problems Faced:



	Severity	Message	Location
1	Information	Solve,-3	

THANK YOU