EE309 – Power Systems Lab

Submitted by –

Chirag Rathi – 2020eeb1165

Yash Agrawal – 2020eeb1220

Term Project

Statement

Take the IEEE 14-bus system, and write a MatLab code for computing DC load flow. Run it under the base case. Print results. Now write a MatLab code for ranking N-1 contingencies using GSF and LODF.

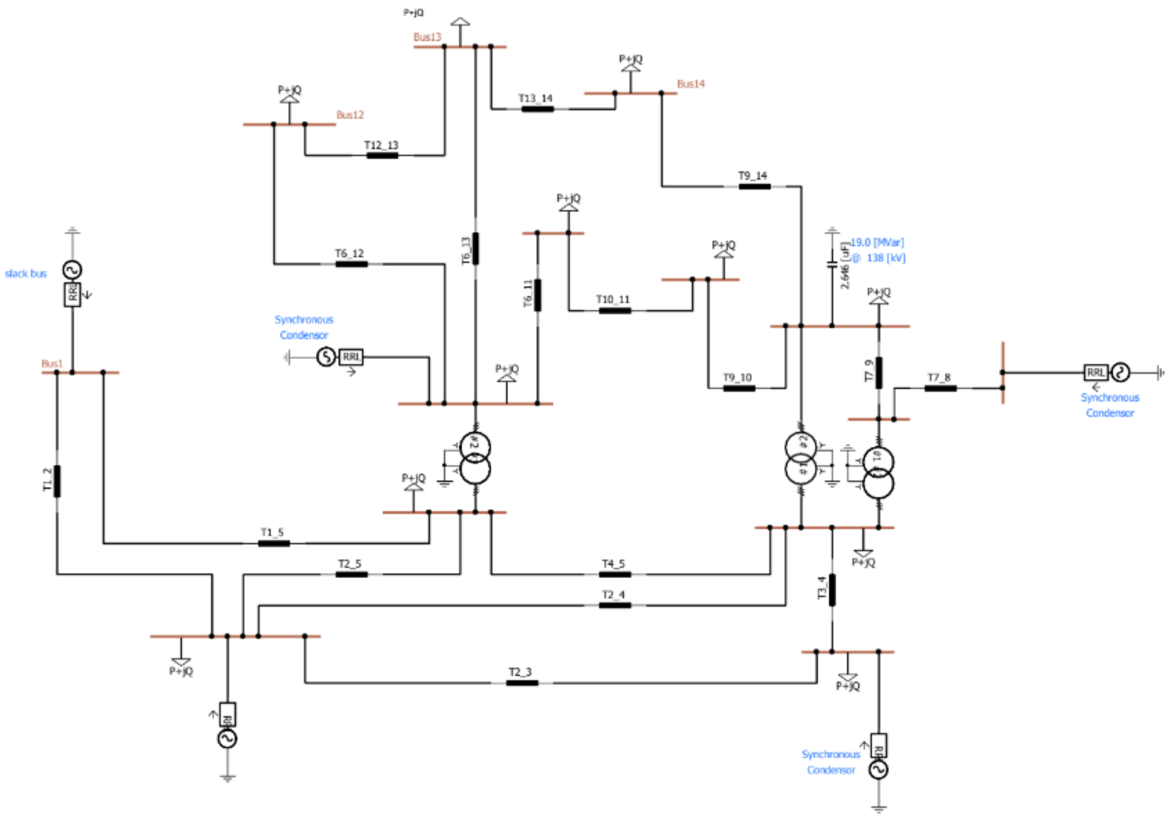

Fig1 – Model representation of IEEE 14-bus System

Theory

Contingency is the loss or failure of a small part of the power system or the loss/failure of individual equipment like a generator or transformer. Contingency Analysis comprises what if scenarios. It is done to ensure power security. There are two types of Contingencies (outages):

- Power outage - This is Generator outage.
- Network outage - This is a transformer or transmission line outage.

Ranking contingencies is listing of contingencies where probability of occurrence is high. Is the system secure? This is seen via:

- Line flows (Real power flows)
- Voltage limits

Contingency is a two-step method.

- Contingency Selection
- Contingency Analysis

Contingency selection can be done by two methods Ranking basis and Screening Method.

Ranking method is a straightaway method, which involves repeatedly running the DC load flow analysis after N-1 contingencies to get the performance index. Analysing the performance index values enables the contingency rating. The item with the greatest PI value is considered to be the most sensitive, and is given it rank 1.

Screening method is an indirect method, which involves the sensitivity analysis of change in power flows, voltage and reactive power. And ranking them according to sensitivity factors. There are two types of sensitivity factors: -

- Generation Shift Factor (When generator is out)
- Load Outage Distribution Factor (When line is out)

Generator shift factor is the sensitivity factor when a generator is out from the power system.

$$a_{li} = \frac{\Delta f_l}{\Delta P_i}$$

$$a_{li} = \frac{X_{ni} - X_{mi}}{X_l}$$

$$f_l^{new} = f_l^{old} + a_{li} * \Delta P$$

Here generator “i” is out from the system and observing the change in power flow in line “l” connecting bus “n” to “m”.

Load distribution outage factor is the sensitivity factor when a line is out from the power system.

$$d_{lk} = \frac{\Delta f_l}{f_k^o}$$

$$d_{lk} = \frac{(\frac{x_k}{x_l})(X_{in} - X_{jn} - X_{im} - X_{jm})}{x_k - (X_{nn} + X_{mm} - 2X_{nm})}$$

$$f_l^{new} = f_l^o + d_{lk} * f_k^o$$

Here line “k” (line connecting from bus “n” to “m”) is out from the system and observing the change in power flow in line “l” (line connecting from bus “I” to “j”). f_l^{new} and f_l^o is the new and old power flow in line “l” respectively. f_k^o is the old power flow in line “k”.

Performance Index (Real power flow PI): -

$$PI_l^c \cong \sum_{i=1}^{N_l} \frac{W_{li}}{2n} \left(\frac{P_{li}}{P_{li}max}\right)^{2n}$$

Where P_{li} : Real power flow in line “l” under contingency C.

W_{li} : Weighing factor of line “l”

n: Exponent

N_l : Number of lines in network

Note: - Here we are considering value for n and W_{li} to be 1.

Procedure

1. Defining IEEE 14-bus System data in vector format.

BaseMVA = 100

```
%         IEEE 14-BUS TEST SYSTEM
%         Bus Bus  Voltage Angle   ---Load---- -------Generator----- Static Mvar
%         No  code Mag.    Degree  MW    Mvar  MW     Mvar     Qmin Qmax    +Qc/-Qlr
busdata=[1   1    1.06    0.0     0.0   0.0   232   -16.01    0    10       0
         2   0    1.045   0.0     21.7  12.7  40     45.41   -42   50       0
         3   0    1.010   0.0     94.2  19.1  0.0    0        23.4 40       0
         4   0    1.0     0.0     47.8  -3.9  0.0    0        0    0        0
         5   0    1.0     0.0     7.6   1.6   0.0    0        0    0        0
         6   0    1.0     0.0     11.2  7.5   0.0    0        0    0        0
         7   0    1.0     0.0     0     0     0.0    0        0    0        0
         8   0    1.0     0.0     0     0     0.0    0        0    0        0
         9   0    1.0     0.0     29.5  16.6  0.0    0        0    0        0
         10  0    1.0     0.0     9     5.8   0.0    0        0    0        0
         11  0    1.0     0.0     3.5   1.8   0.0    0        0    0        0
         12  0    1.0     0.0     6.1   1.6   0.0    0        0    0        0
         13  0    1.0     0.0     13.8  5.8   0.0    0        0    0        0
         14  0    1.0     0.0     14.9  5     0.0    0        0    0        0
         ];
```

```
%                                         Line data
%          Bus bus   R         X         1/2 B       = 1 for lines
%          nl  nr   p.u.      p.u.      p.u.        > 1 or < 1 tr. tap at bus nl
linedata=[1   2    0.01938   0.05917   0.02640     1
          1   5    0.05403   0.22304   0.02190     2
          2   3    0.04699   0.19797   0.01870     3
          2   4    0.05811   0.17632   0.02460     4
          2   5    0.05695   0.17388   0.01700     15
          3   4    0.06701   0.17103   0.01730     6
          4   5    0.01355   0.04211   0.00640     7
          4   7    0         0.20912   0           8
          4   9    0         0.55618   0           9
          5   6    0         0.25202   0           10
          6   11   0.09498   0.1989    0           11
          6   12   0.12291   0.25581   0           12
          6   13   0.06615   0.13027   0           13
          7   8    0         0.17615   0           14
          7   9    0         0.11001   0           15
          9   10   0.03181   0.0845    0           16
          9   14   0.12711   0.27038   0           17
          10  11   0.08205   0.19207   0           18
          12  13   0.22092   0.19988   0           19
          13  14   0.17093   0.34802   0           20];
```

2. DC Load Flow Analysis

```
%% Types of buses--> 1-slack , 2-3-6-8 PV, rest PQ

% Calculating B matrix
B = zeros(14,14);
j  = 1;

for i = 1:1:14
    for j = 1:1:14
        val = 0;
        if i == j
            for k = 1:1:20
                if (linedata(k,1) == i) || (linedata(k,2) == i)
                    val = val + (1/linedata(k,4));
                end
            end
        else
            for k = 1:1:20
                if (linedata(k,1) == i && linedata(k,2) == j) || (linedata(k,1) == j && linedata(k,2) == i)
                    val = -(1/linedata(k,4));
                end
            end
        end
        B(i,j) = val;
    end
end
%% Calculating P matrix
P = zeros(14,1);
for m = 1:1:14
    P(m,1) = (busdata(m,7) - busdata(m,5))/basemva;
end
%% Calculation of power angles
B1 = B;
P1 = P;
P1(1,:) = [];
B1(1,:) = [];
B1(:,1) = [];
del = B1\P1;
%% Calculation of line power flows (initial)
d1 = del';
d2 = [0,d1];
PA = d2';

Pl = zeros(1,20);
for i = 1:1:20
    Pl(1,i) =  (PA(linedata(i,1))-PA(linedata(i,2)))/linedata(i,4);
end
pf = Pl';
```

3. Calculating LODF

```
%% calculation of X
Bb = B;
Bb(:,1) = [];
Bb(1,:) = [];
X = inv(Bb);

Xx = zeros(14,14);

for i = 2:1:14
    for j = 2:1:14
        Xx(i,j) = X(i-1,j-1);
    end
end
```

```
%% Calculation of dlk (LODF)

del_pf = zeros(20,20);
dlk = zeros(20,20);
for i = 1:1:20
    del_pf(:,i) = pf_new(:,i) - pf;
    dlk(:,i) = del_pf(:,i)/pf(i,1);
end
```

```
%% calculating dlk (LODF)

% n,m -> out , checking -> i,j
% k -> out , l-> check
dlk = zeros(20,20);
delfl = zeros(20,20);
pf_new = zeros(20,20);

for k = 1 : 1 : 20
    n = linedata(k,1);
    m = linedata(k,2);
    for l = 1:1:20
        i = linedata(l,1);
        j = linedata(l,2);
        dlk(k,l) = ((linedata(k,4)/linedata(l,4)) * (Xx(i,n) - Xx(j,n) - Xx(i,m) + Xx(j,m))) / (linedata(k,4) - (Xx(n,n)+Xx(m,m)-2*Xx(n,m)));
        delfl(k,l) = dlk(k,l) * pf(k,1);
        pf_new(k,l) = pf(l,1) + delfl(k,l);
    end
end
```

4. Calculating GSF

```
%% GSF
% (only outing generator on bus 2)

al2 = zeros(1,20);
fl_new = zeros(1,20);
for  l = 1:1:20
    n = linedata(l,1);
    m = linedata(l,2);
    al2(1,l) = (Xx(n,2) - Xx(m,2))/linedata(l,4);
    fl_new(1,l) = pf(l,1) + al2(1,l) * (-0.4);
end
```

5. Ranking using performance indices for real power flow

```
%% Ranking the contingency
PIr = zeros(20,2);

for l = 1:1:20
    for k = 1:1:20
    PIr(l,1) = PIr(l,1) + 1/2 * (pf_new(l,k)/1)^2 ;  %assume Pmax = 1 , for each line
    PIr(l,2) = l;
    end
end


Pig =0;
for i = 1:1:20
    Pig = Pig + 1/2 * (fl_new(1,i)/1)^2;
end

PIr_new = zeros(21,2);

for i = 1:1:20
    PIr_new(i,1) = PIr(i,1);
    PIr_new(i,2) = PIr(i,2);
end
PIr_new(21,1) = Pig;
PIr_new(21,2) = 21;


PIr_new = sortrows(PIr_new,1,"descend");
```

PIr_new is 21X2 matrix containing performance index. From row 1 to 20 it represents performance index of line outage and row 21 represents performance index of generator number 2 outage.

Results

1. DC Load Flow Analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	21.3840	-16.9005	0	0	-4.4835	0	0	0	0	0	0	0	0	0
2	-16.9005	33.3743	-5.0513	-5.6715	-5.7511	0	0	0	0	0	0	0	0	0
3	0	-5.0513	10.8982	-5.8469	0	0	0	0	0	0	0	0	0	0
4	0	-5.6715	-5.8469	41.8457	-23.7473	0	-4.7819	0	-1.7980	0	0	0	0	0
5	-4.4835	-5.7511	0	-23.7473	37.9499	-3.9679	0	0	0	0	0	0	0	0
6	0	0	0	0	-3.9679	20.5811	0	0	0	0	-5.0277	-3.9092	-7.6764	0
7	0	0	0	-4.7819	0	0	19.5490	-5.6770	-9.0901	0	0	0	0	0
8	0	0	0	0	0	0	-5.6770	5.6770	0	0	0	0	0	0
9	0	0	0	-1.7980	0	0	-9.0901	0	26.4209	-11.8343	0	0	0	-3.6985
10	0	0	0	0	0	0	0	0	-11.8343	17.0408	-5.2064	0	0	0
11	0	0	0	0	0	-5.0277	0	0	0	-5.2064	10.2341	0	0	0
12	0	0	0	0	0	-3.9092	0	0	0	0	0	8.9122	-5.0030	0
13	0	0	0	0	0	-7.6764	0	0	0	0	0	-5.0030	15.5528	-2.8734
14	0	0	0	0	0	0	0	0	-3.6985	0	0	0	-2.8734	6.5719

Fig 1 – B matrix for original 14-bus system

	1
1	0.1830
2	-0.9420
3	-0.4780
4	-0.0760
5	-0.1120
6	0
7	0
8	-0.2950
9	-0.0900
10	-0.0350
11	-0.0610
12	-0.1380
13	-0.1490

Fig 2 – P matrix

	1
1	-0.0876
2	-0.2264
3	-0.1851
4	-0.1589
5	-0.2654
6	-0.2459
7	-0.2459
8	-0.2779
9	-0.2831
10	-0.2778
11	-0.2848
12	-0.2878
13	-0.3049

Fig 3 – Del matrix

	1
1	1.4807
2	0.7123
3	0.7009
4	0.5530
5	0.4098
6	-0.2411
7	-0.6234
8	0.2906
9	0.1667
10	0.4227
11	0.0626
12	0.0760
13	0.1721
14	3.1514e-16
15	0.2906
16	0.0624
17	0.0999
18	-0.0276
19	0.0150
20	0.0491

Fig 4 – Power flow in each line

2. LODF

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5.1738	1.0000	-0.1688	-0.3533	-0.4779	-0.1688	-0.4940	-0.0178	-0.0102	0.0281	0.0169	0.0025	0.0087	0	-0.0178	-0.0169	-0.0112	-0.0169	0.0025	0.0112
2	1.0000	0.6379	0.1688	0.3533	0.4779	0.1688	0.4940	0.0178	0.0102	-0.0281	-0.0169	-0.0025	-0.0087	1.2904e-16	0.0178	0.0169	0.0112	0.0169	-0.0025	-0.0112
3	-0.2076	0.2076	1.2695	0.4554	0.3370	-1.0000	-0.5153	-0.0186	-0.0107	0.0293	0.0176	0.0026	0.0091	0	-0.0186	-0.0176	-0.0116	-0.0176	0.0026	0.0116
4	-0.2724	0.2724	0.2855	0.5975	0.4421	0.2855	-0.6761	-0.0244	-0.0140	0.0384	0.0231	0.0034	0.0119	1.2585e-16	-0.0244	-0.0231	-0.0153	-0.0231	0.0034	0.0153
5	-0.3606	0.3606	0.2067	0.4327	0.5853	0.2067	0.6050	0.0218	0.0125	-0.0344	-0.0207	-0.0030	-0.0106	1.2489e-16	0.0218	0.0207	0.0137	0.0207	-0.0030	-0.0137
6	-0.2076	0.2076	-1	0.4554	0.3370	1.6270	-0.5153	-0.0186	-0.0107	0.0293	0.0176	0.0026	0.0091	2.0696e-16	-0.0186	-0.0176	-0.0116	-0.0176	0.0026	0.0116
7	-0.2919	0.2919	-0.2475	-0.5181	0.4737	-0.2475	4.1253	0.1489	0.0855	-0.2344	-0.1411	-0.0207	-0.0725	0	0.1489	0.1411	0.0932	0.1411	-0.0207	-0.0932
8	-0.0294	0.0294	-0.0249	-0.0521	0.0477	-0.0249	0.4151	1.8767	0.5078	0.4922	0.2964	0.0435	0.1523	0	-1.0000	-0.2964	-0.1958	-0.2964	0.0435	0.1958
9	-0.0213	0.0213	-0.0181	-0.0379	0.0346	-0.0181	0.3014	0.6426	0.3687	0.3574	0.2152	0.0316	0.1106	0	0.6426	-0.2152	-0.1422	-0.2152	0.0316	0.1422
10	0.0597	-0.0597	0.0506	0.1059	-0.0969	0.0506	-0.8435	0.6354	0.3646	2.0816	-0.6022	-0.0884	-0.3094	0	0.6354	0.6022	0.3978	0.6022	-0.0884	-0.3978
11	0.0355	-0.0355	0.0301	0.0630	-0.0576	0.0301	-0.5017	0.3779	0.2169	-0.5948	2.8567	0.0901	0.3151	0	0.3779	1.0000	-0.4052	1.0000	0.0901	0.4052
12	0.0039	-0.0039	0.0033	0.0069	-0.0063	0.0033	-0.0546	0.0412	0.0236	-0.0648	0.0668	1.2236	0.8684	-3.5037e-16	0.0412	-0.0668	0.1316	-0.0668	-1.0000	-0.1316
13	0.0102	-0.0102	0.0086	0.0181	-0.0165	0.0086	-0.1438	0.1084	0.0622	-0.1705	0.1759	0.6536	2.2863	-5.1782e-16	0.1084	-0.1759	0.3464	-0.1759	0.6536	-0.3464
14	0	-0.3949	0	-0.4995	-0.5065	-0.5150	0	0	0	0	0	0.6886	1.3522	-6.3465e+15	0	2.0846	0	-0.9171	0	-0.5061
15	-0.0294	0.0294	-0.0249	-0.0521	0.0477	-0.0249	0.4151	-1.0000	0.5078	0.4922	0.2964	0.0435	0.1523	0	4.4683	-0.2964	-0.1958	-0.2964	0.0435	0.1958
16	-0.0355	0.0355	-0.0301	-0.0630	0.0576	-0.0301	0.5017	-0.3779	-0.2169	0.5948	1.0000	-0.0901	-0.3151	-1.4304e-15	-0.3779	8.0782	0.4052	-1.0000	-0.0901	-0.4052
17	-0.0294	0.0294	-0.0249	-0.0521	0.0477	-0.0249	0.4152	-0.3128	-0.1795	0.4923	-0.5077	0.2223	0.7777	0	-0.3128	0.5077	2.5546	0.5077	0.2223	1.0000
18	-0.0355	0.0355	-0.0301	-0.0630	0.0576	-0.0301	0.5017	-0.3779	-0.2169	0.5948	1	-0.0901	-0.3151	6.2931e-16	-0.3779	-1.0000	0.4052	2.9939	-0.0901	-0.4052
19	0.0039	-0.0039	0.0033	0.0069	-0.0063	0.0033	-0.0546	0.0412	0.0236	-0.0648	0.0668	-1.0000	0.8684	0	0.0412	-0.0668	0.1316	-0.0668	1.8458	-0.1316
20	0.0294	-0.0294	0.0249	0.0521	-0.0477	0.0249	-0.4152	0.3128	0.1795	-0.4923	0.5077	-0.2223	-0.7777	4.3514e-16	0.3128	-0.5077	1	-0.5077	-0.2223	1.7616

Fig 5 – LODF factors dji

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	9.1299	2.1900	0.4509	0.0298	-0.2977	-0.4911	-1.3540	0.2635	0.1512	0.4623	0.0880	0.0791	0.1832	-1.5757e-16	0.2635	0.0370	0.0827	-0.0530	0.0181	0.0663
2	2.1900	1.1648	0.8206	0.8035	0.7489	-0.1214	-0.2720	0.3025	0.1736	0.4009	0.0510	0.0737	0.1642	-6.5798e-17	0.3025	0.0740	0.1072	-0.0160	0.0127	0.0418
3	1.3334	0.8566	1.5898	0.8713	0.6451	-0.9420	-0.9844	0.2768	0.1588	0.4413	0.0754	0.0773	0.1767	-1.5757e-16	0.2768	0.0496	0.0911	-0.0404	0.0163	0.0579
4	1.3284	0.8616	0.8582	0.8822	0.6532	-0.0838	-0.9968	0.2764	0.1586	0.4421	0.0758	0.0773	0.1769	-8.8063e-17	0.2764	0.0492	0.0908	-0.0408	0.0163	0.0582
5	1.3313	0.8587	0.7851	0.7292	0.6484	-0.1569	-0.3759	0.2988	0.1714	0.4068	0.0546	0.0742	0.1660	-1.0648e-16	0.2988	0.0704	0.1048	-0.0196	0.0132	0.0442
6	1.5289	0.6611	0.9420	0.4423	0.3277	-0.6344	-0.4989	0.2943	0.1689	0.4138	0.0588	0.0748	0.1681	-2.0755e-16	0.2943	0.0662	0.1020	-0.0238	0.0138	0.0470
7	1.6608	0.5292	0.8548	0.8752	0.1137	-0.0872	-3.1951	0.1970	0.1130	0.5670	0.1510	0.0884	0.2155	-1.5757e-16	0.1970	-0.0260	0.0411	-0.1160	0.0274	0.1079
8	1.4703	0.7197	0.6933	0.5372	0.4229	-0.2487	-0.5031	0.8338	0.3135	0.5635	0.1490	0.0881	0.2145	-1.5757e-16	-1.2212e-15	-0.0240	0.0425	-0.1140	0.0271	0.1065
9	1.4753	0.7147	0.6975	0.5460	0.4148	-0.2445	-0.5733	0.3967	0.2276	0.4803	0.0988	0.0807	0.1887	-1.5757e-16	0.3967	0.0262	0.0756	-0.0638	0.0197	0.0734
10	1.5039	0.6861	0.7218	0.5968	0.3683	-0.2202	-0.9784	0.5573	0.3197	1.2969	-0.1904	0.0382	0.0401	-1.5757e-16	0.5573	0.3154	0.2666	0.2254	-0.0228	-0.1176
11	1.4810	0.7090	0.7024	0.5562	0.4054	-0.2396	-0.6550	0.3137	0.1800	0.3833	0.2432	0.0811	0.1902	-1.5757e-16	0.3137	0.1250	0.0737	0.0350	0.0201	0.0753
12	1.4791	0.7109	0.7007	0.5528	0.4086	-0.2413	-0.6275	0.2930	0.1681	0.4159	0.0681	0.1678	0.2359	-1.8400e-16	0.2930	0.0569	0.1091	-0.0331	-0.0610	0.0399
13	1.4805	0.7095	0.7020	0.5553	0.4062	-0.2400	-0.6479	0.3083	0.1769	0.3918	0.0930	0.1868	0.5598	-2.4577e-16	0.3083	0.0320	0.1582	-0.0580	0.1258	-0.0092
14	1.4788	0.7112	0.7005	0.5523	0.4090	-0.2415	-0.6234	0.2899	0.1663	0.4208	0.0630	0.0755	0.1703	1.0000	0.2899	0.0620	0.0992	-0.0280	0.0145	0.0498
15	1.4703	0.7197	0.6933	0.5372	0.4229	-0.2487	-0.5031	3.3307e-16	0.3135	0.5635	0.1490	0.0881	0.2145	-1.5757e-16	1.5850	-0.0240	0.0425	-0.1140	0.0271	0.1065
16	1.4766	0.7134	0.6986	0.5484	0.4126	-0.2434	-0.5923	0.2664	0.1529	0.4577	0.1250	0.0699	0.1508	-2.4619e-16	0.2664	0.5624	0.1243	-0.0900	0.0089	0.0247
17	1.4759	0.7141	0.6980	0.5471	0.4138	-0.2440	-0.5822	0.2588	0.1485	0.4697	0.0127	0.0975	0.2475	-1.5757e-16	0.2588	0.1123	0.3527	0.0223	0.0365	0.1490
18	1.4798	0.7102	0.7013	0.5540	0.4074	-0.2407	-0.6375	0.3005	0.1724	0.4042	0.0350	0.0780	0.1792	-1.7522e-16	0.3005	0.0900	0.0878	-0.1120	0.0170	0.0612
19	1.4789	0.7111	0.7005	0.5524	0.4089	-0.2415	-0.6242	0.2904	0.1667	0.4199	0.0640	0.0610	0.1829	-1.5757e-16	0.2904	0.0610	0.1011	-0.0290	0.0411	0.0479
20	1.4803	0.7097	0.7017	0.5549	0.4067	-0.2403	-0.6441	0.3054	0.1752	0.3963	0.0883	0.0644	0.1316	-1.3590e-16	0.3054	0.0367	0.1490	-0.0533	0.0034	0.1375

Fig 1 – New power flow in line **j** due to outage of line **i**

3. GSF

	1
1	1.8140
2	0.7760
3	0.6896
4	0.5294
5	0.3781
6	-0.2524
7	-0.6554
8	0.2887
9	0.1657
10	0.4227
11	0.0641
12	0.0756
13	0.1709
14	-1.5757e-16
15	0.2887
16	0.0609
17	0.0985
18	-0.0291
19	0.0146
20	0.0505

Fig 1 – New power flow in line **i** due to outage of Generator at BUS 2

	1
1	-0.8380
2	-0.1620
3	0.0273
4	0.0572
5	0.0774
6	0.0273
7	0.0800
8	0.0029
9	0.0017
10	-0.0045
11	-0.0027
12	-4.0213e-04
13	-0.0014
14	0
15	0.0029
16	0.0027
17	0.0018
18	0.0027
19	-4.0213e-04
20	-0.0018

Fig 1 – GSF factor al2

4. Ranking using PI for real power flow.

	1	2
1	45.4787	1
2	7.6406	7
3	4.2748	2
4	4.2515	3
5	3.7156	10
6	3.4870	15
7	2.9407	4
8	2.8568	21
9	2.7656	14
10	2.5785	8
11	2.5223	6
12	2.4580	13
13	2.4085	16
14	2.3489	9
15	2.3361	5
16	2.3280	11
17	2.3265	17
18	2.2958	12
19	2.2910	20
20	2.2844	18
21	2.2683	19

Fig 1 – Ranking Contingency based on the performance index

Conclusion: -

In the above term project, we performed DC load flow analysis on IEEE 14 bus system.

Then we have done contingency analysis by calculating GSF and LODF sensitivity factors as well as new power flow and ranking them on the basis of performance index (PI_l^c).

From the above analysis we can conclude that outage of line 1, 7, 2, 3 and 10 are the top 5 most critical contingencies.