Power Flow Analysis of IEEE 30 Bus System

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Abstract: **- India is a large populated country and the electricity supply need of this population creates requirement of large transmission and distribution system. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. The improvement in power scenario will affect the economic development of a country. So it is necessary to give prior importance in power improvement. Line losses play an important role in its efficiency. Reduction in its losses will improve the power scenario in India. With this view, this paper describes the variations of active and reactive power losses at different buses.**

I. INTRODUCTION

Line flow analysis (LFA) is used to make sure that electrical power transfer from generator stations to consumers end through the grid system in reliable and economical form. Conventional techniques for line flow analysis problem are iterative mathematical method like the Newton-Raphson (NR) or the Gauss-Seidel (GS) methods. An engineer is always concerned about economical condition of the system operation. For the mighty interconnected grid system, the power shortage results continuous hike in prices. Thus, it is the priority of engineer to control this continuous hike. Another major problem is economic load dispatch in an optimized manner as it is directly related with load demands. For economically optimized operation of interconnected grid system modern system theory and optimization techniques are being applied with the optimized generation cost function. Through the line flow study, the voltage magnitude and angle at each bus under the steady state can be obtained.

Line flow analysis (LFA) is very important tool for analysis of power systems which is used at operational as well as planning stages of the system, like adding and installation of new generation station, load balancing in dynamic running condition and transmission lines site selection. The LFA gives the voltage and phase angle at each bus which is further used to determine the power injection at all the busses along with power flow through interconnected nodes. All these system parameter obtained values are needed for determining the optimal location as well as optimal capacity of proposed generation station, substation and new lines. In order to avoid the system unbalance condition, the voltage should be maintained within its tolerance limit with minimized line transmission losses.

Classification of Buses

In an electrical power system all the buses constitutes of four variables, which are voltage magnitude, voltage phase angle, active power and reactive power in line flow.

For power flow solution out of these four variables, two are made constant and two are treated as variable. All the buses are categorised on the basis of the constant parameters. (Fig 1)

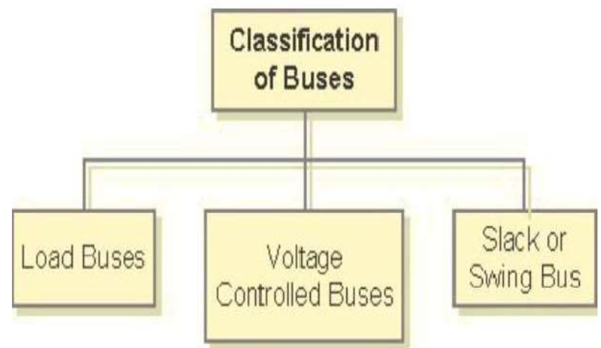

Fig. 1 Classification of buses.

1) *Load bus:* At this bus, the real and reactive powers are specified. Voltage and phase angles are not defined. No generators are attached with this bus.

2) *Generator bus:* This bus is also called as voltage controlled bus. Here the voltage magnitude corresponding to the generator voltage and real power (Pg) are specified. Reactive power generation (Qg) and voltage phase angle are the unknown parameter for line flow calculations.

3) *Slack Bus:* It is also known as Swing Bus. In this bus it is assumed that voltage magnitude and phase angle is known parameters. The real power generated (Pg) and the reactive power generated (Qg) are considered as unknown parameter.

Newton Raphson Method

Newton Raphson method is the best opted method for solving non-linear load flow equations as it gives better convergence speed as compare to other load flow methods. The number of iterations involved in Newton Raphson method is independent of number of buses considered, hence power flow equations can be solved just in few iterations. Newton Raphson method transforms the set of non-linear equations into a set of linear equations which approach to the original solution efficiently.

Objectives of the paper

This paper aims to investigate the effect of applying Newton Raphson method in calculation of power flow in a IEEE 30 bus system. The real power loss and reactive power loss have been calculated and plotted for different branches. The real power demand has been increased by 5 Mw in 3 steps and the load flow solution has been carried out for each cases. The main objective is to analyse the scenario of real power loss and reactive power loss for all the mentioned cases.

II. STUDY AREA AND OBJECTS

IEEE 30 bus system has been selected for our case study. Firstly, existing real power demand is taken for analysis. Further real power demand is increased stepwise and loss analysis has been carried out.

III. RESULTS AND ANALYSIS

The bus data for IEEE 30 bus system is presented in Table 1.1. The generated real power and reactive along with voltages and angles are given for some selected bus.

BUS DATA					
Bus	Voltage		Generation		Load
	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)
1	1	0	25.97	-1	-
2	1	-0.415	60.97	32	21.7
3	0.983	-1.522	-	-	2.4
4	0.98	-1.795	-	-	7.6
5	0.982	-1.864	-	-	-
6	0.973	-2.267	-	-	-
7	0.967	-2.652	-	-	22.8
8	0.961	-2.726	-	-	30
9	0.981	-2.997	-	-	-
10	0.984	-3.375	-	-	5.8
11	0.981	-2.997	-	-	-
12	0.985	-1.537	-	-	11.2
13	1	1.476	37	11.35	-
14	0.977	-2.308	-	-	6.2
15	0.98	-2.312	-	-	8.2
16	0.977	-2.644	-	-	3.5
17	0.977	-3.392	-	-	9
18	0.968	-3.478	-	-	3.2
19	0.965	-3.958	-	-	9.5
20	0.969	-3.871	-	-	2.2
21	0.993	-3.488	-	-	17.5
22	1	-3.393	21.59	39.57	-
23	1	-1.589	19.2	7.95	3.2
24	0.989	-2.631	-	-	8.7
25	0.99	-1.69	-	-	-
26	0.972	-2.139	-	-	3.5
27	1	-0.828	26.91	10.54	-
28	0.975	-2.266	-	-	-
29	0.98	-2.128	-	-	2.4
30	0.968	-3.042	-	-	10.6
Total			191.64	100.41	189.2

Table 1

Case 1: When Real power loads at bus no 2 is 21.7 MW (Existing Case)

The base case analysis have been carried out and it is seen that the highest real power loss is taken place at bus no 6 and corresponding highest reactive power loss is at bus no 16.

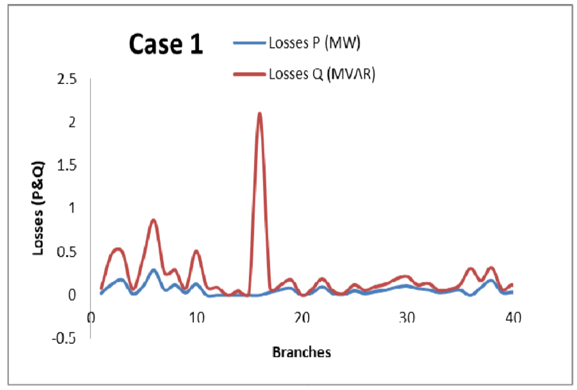

Fig 2. Real and Reactive Power loss

CASE 1				
When Real power load at bus no 2 is 21.7				
Branch	From Bus	To Bus	Losses	
			P (MW)	Q (MVAR)
1	1	2	0.026	0.08
2	1	3	0.127	0.48
3	2	4	0.178	0.5
4	3	4	0.018	0.07
5	2	5	0.11	0.44
6	2	6	0.289	0.87
7	4	6	0.066	0.26
8	5	7	0.12	0.29
9	6	7	0.031	0.08
10	6	8	0.128	0.51
11	6	9	0	0.1
12	6	10	0	0.09
13	9	11	0	0
14	9	10	0	0.05
15	4	12	0	0.02
16	12	13	0	2.1
17	12	14	0.037	0.08
18	12	15	0.066	0.12
19	12	16	0.08	0.18
20	14	15	0.003	0
21	16	17	0.031	0.07
22	15	18	0.097	0.19
23	18	19	0.022	0.05
24	19	20	0.009	0.02
25	10	20	0.052	0.12
26	10	17	0.023	0.06
27	10	21	0.044	0.1
28	10	22	0.062	0.13
29	21	22	0.093	0.19
30	15	23	0.109	0.22
31	22	24	0.078	0.12
32	23	24	0.066	0.14
33	24	25	0.035	0.06
34	25	26	0.046	0.07
35	25	27	0.063	0.12
36	28	27	0	0.31
37	27	29	0.09	0.17
38	27	30	0.171	0.32
39	29	30	0.035	0.07
40	8	28	0.036	0.12
41	6	28	0.001	0
Total			2.444	8.99

Table3: Real and Reactive power loss

The real power loss and reactive power loss for different buses are calculated and are shown in fig2 and Table 3.

Case 2: When Real power loads at bus no 2 is increases to 30 MW

CASE 2				
When Real power load at bus no 2 is increased to 30				
Branch	From Bus	To Bus	Losses	
			P (MW)	Q (MVAR)
1	1	2	0.112	0.34
2	1	3	0.202	0.77
3	2	4	0.188	0.53
4	3	4	0.031	0.13
5	2	5	0.096	0.38
6	2	6	0.251	0.75
7	4	6	0.035	0.14
8	5	7	0.098	0.24
9	6	7	0.048	0.13
10	6	8	0.106	0.43
11	6	9	0	0.2
12	6	10	0	0.18
13	9	11	0	0
14	9	10	0	0.11
15	4	12	0	0.75
16	12	13	0	1.81
17	12	14	0.03	0.06
18	12	15	0.03	0.05
19	12	16	0.047	0.1
20	14	15	0.006	0.01
21	16	17	0.01	0.02
22	15	18	0.073	0.15
23	18	19	0.014	0.03
24	19	20	0.009	0.02
25	10	20	0.055	0.13
26	10	17	0.017	0.05
27	10	21	0.04	0.09
28	10	22	0.062	0.13
29	21	22	0.095	0.19
30	15	23	0.134	0.27
31	22	24	0.037	0.06
32	23	24	0.016	0.03
33	24	25	0.229	0.4
34	25	26	0.041	0.06
35	25	27	0.239	0.46
36	28	27	0	2.19
37	27	29	0.078	0.15
38	27	30	0.149	0.28
39	29	30	0.03	0.06
40	8	28	0.066	0.22
41	6	28	0.041	0.12
Total			2.716	12.21

Table 4: Real and Reactive power loss

In this case the real power demand of bus no 2 is increased to 30MW and the variations in real power loss and reactive power loss is noted down.

The real and reactive power losses are plotted in a single graph and are shown in Fig 2. It shows the variations

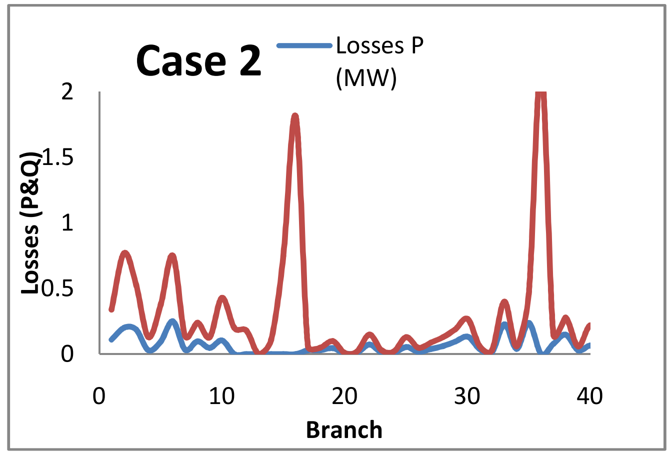

Fig 3. Real and Reactive Power loss

The real power loss and reactive power loss for different buses are calculated and are shown in fig 3 and Table 4.

Case 3: When Real power loads at bus no 2 is increases to 35 MW

In this case the real power demand of bus no 2 is increased to 35 MW and the variations in real power loss and reactive power loss is noted down.

The real and reactive power losses are plotted in a single graph and are shown in Fig 4. It shows the variations

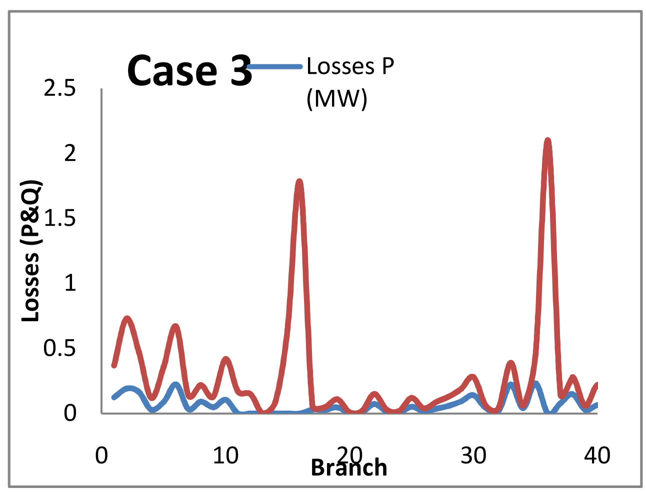

Fig 4. Real and Reactive Power loss

CASE 3				
When Real power load at bus no 2 is increased to 35				
Branch	**From Bus**	**To Bus**	**Losses**	
			P (MW)	**Q (MVAR)**
1	1	2	0.124	0.37
2	1	3	0.192	0.73
3	2	4	0.165	0.47
4	3	4	0.03	0.12
5	2	5	0.09	0.36
6	2	6	0.224	0.67
7	4	6	0.034	0.14
8	5	7	0.092	0.22
9	6	7	0.048	0.13
10	6	8	0.105	0.42
11	6	9	0	0.17
12	6	10	0	0.15
13	9	11	0	0
14	9	10	0	0.09
15	4	12	0	0.65
16	12	13	0	1.78
17	12	14	0.029	0.06
18	12	15	0.028	0.05
19	12	16	0.048	0.11
20	14	15	0.006	0.01
21	16	17	0.01	0.02
22	15	18	0.074	0.15
23	18	19	0.015	0.03
24	19	20	0.009	0.02
25	10	20	0.053	0.12
26	10	17	0.017	0.04
27	10	21	0.038	0.09
28	10	22	0.06	0.13
29	21	22	0.094	0.19
30	15	23	0.141	0.28
31	22	24	0.041	0.06
32	23	24	0.019	0.04
33	24	25	0.224	0.39
34	25	26	0.041	0.06
35	25	27	0.233	0.45
36	28	27	0	2.1
37	27	29	0.078	0.15
38	27	30	0.149	0.28
39	29	30	0.03	0.06
40	8	28	0.065	0.22
41	6	28	0.038	0.11
Total			**2.644**	**11.69**

Table 5: Real and Reactive power loss

Case 4: When Real power loads at bus no 2 is increases to 40 MW

In this case the real power demand of bus no 2 is increased to 40 MW and the variations in real power loss and reactive power loss is noted down.

CASE 4				
When Real power load at bus no 2 is increased to 40				
Branch	**From Bus**	**To Bus**	**Losses**	
			P (MW)	**Q (MVAR)**
1	1	2	0.137	0.41
2	1	3	0.182	0.69
3	2	4	0.143	0.41
4	3	4	0.028	0.11
5	2	5	0.083	0.33
6	2	6	0.199	0.6
7	4	6	0.034	0.13
8	5	7	0.087	0.21
9	6	7	0.049	0.13
10	6	8	0.104	0.42
11	6	9	0	0.15
12	6	10	0	0.13
13	9	11	0	0
14	9	10	0	0.08
15	4	12	0	0.57
16	12	13	0	1.76
17	12	14	0.028	0.06
18	12	15	0.027	0.05
19	12	16	0.048	0.11
20	14	15	0.007	0.01
21	16	17	0.011	0.03
22	15	18	0.075	0.15
23	18	19	0.015	0.03
24	19	20	0.008	0.02
25	10	20	0.051	0.12
26	10	17	0.016	0.04
27	10	21	0.036	0.08
28	10	22	0.058	0.12
29	21	22	0.093	0.19
30	15	23	0.147	0.29
31	22	24	0.046	0.07
32	23	24	0.022	0.05
33	24	25	0.22	0.38
34	25	26	0.041	0.06
35	25	27	0.228	0.44
36	28	27	0	2.03
37	27	29	0.078	0.15
38	27	30	0.149	0.28
39	29	30	0.03	0.06
40	8	28	0.064	0.21
41	6	28	0.036	0.11
Total			**2.58**	**11.27**

Table 6: Real and Reactive power loss

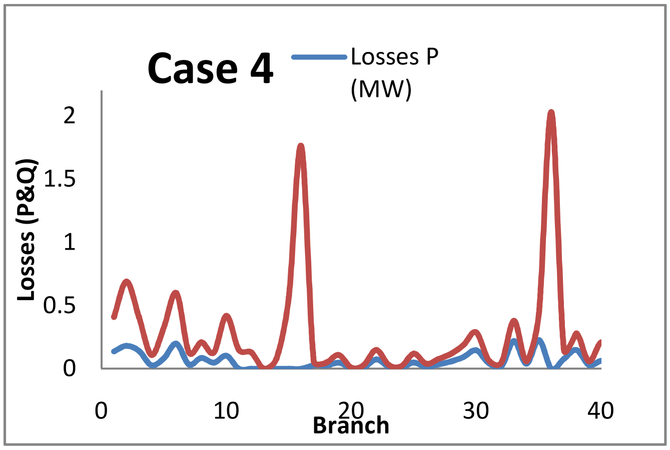

Fig 5. Real and Reactive Power loss

Cases	P Losses (KW)	Q Losses (KVAR)
Case 1	2.444	8.99
Case 2	2.716	12.21
Case 3	2.644	11.69
Case 4	2.58	11.27

Table 7: Loss Variations

IV. CONCLUSION

The real power variations and voltage profile can indicate the need of improving in respect to voltage and load requirement. Loss optimization can also be possible with the use of corrective measures.

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