Quest Journals
Journal of Electronics and Communication Engineering Research
Volume 8 ~ Issue 2 (2022) pp: 01-07
ISSN(Online) : 2321-5941
www.questjournals.org

Research Paper

Analysis Of Power Flow In High Voltage Network

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Abstract– *Load Flow solution provides power flow and voltage for specified power system subject to the regulation capability of generators, setting of load tap changes. And tap changing under load transformer as well as specified grid interchange between individual operating system. This information is essential for continuous evaluation of the current performance of a power system and for analyzing the effectiveness of alternative plans for system expansion to meet increased load demand.*
Analysis of power flow in Enhanced network is performed. The results are analyzed from point of view of voltage drop, power losses, line loading (current carrying capacity) For Enhancement network, The bus voltages and line loading (current in lines) of the Enhancement network are with a required range, that voltages between 90% and 100% of nominal voltage (110kv) and line loading less than 80% of line current carrying capacity these conditions should be fulfilled at normal operation.
Then Estimation of load growth, it can be supposed that load will grow in time, which will have influence on voltage and current relation, the two scenarios are taken into account, load growth 1% per year, the estimation is done for the period of ten and twenty years.
From the results there were found out that the enhanced network is sufficient for next twenty years, from the point of view of voltages as well as line loading (current carrying capacity) for normal operation.

***R**eceived 05 Feb, 2022; **R**evised 15 Feb, 2022; **A**ccepted 18 Feb, 2022 © The author(s) 2022.*
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I. INTRODUCTION

It mentions basic ideas concerning load flow solution and methods of load flow solution and it describes in detail the N-Raphson method that is used load flow solution of a given HV network is performed the results are analysed from point of view of voltage drops, power losses, line loading. Voltage are between 90 and 100% of nominal voltage (110KV) and line loading (currents in lines) is less than 80% of line current carrying capacity. Load flow solution of the enhanced network is performed for normal operation then supposed that load will grow in time which will have influence on voltage and power flow relation in the network. Two scenarios are taken into account, load growth 1% per year. The estimation is done for the period of ten and twenty years.

II. LOAD FLOW SOLUTION

Load flow solution provides power flow and voltage for a specified power system subject to the regulation capability of generators setting of load tap changers, and tap changing under load transformer as well as specified power flow between individual operating system. This information is essential for continuous evaluation of the current performance of a power system and for analyzing the effectiveness of alternative plans for system expansion to meet increased load demand. The load flow problem consists of calculation of power flow and voltage of network for specified terminal or bus conditions.

A singl phase representation is adequate since power systems are usually balanced. Associated with each bus are four quantities:

- ♦ Voltage magnitude V
- ♦ Voltage phase angl δ
- ♦ Real power P
- ♦ Reactive powe Q

In the bus, two of the quantities are specified, the other two are to be found during load flow solution.

- Vδ bus – slack bus – voltage magnitude and phase are specified, this bus covers the losses and the difference between loads and supplies.
- PQ bus – load bus – real and reactive Power is given.
- PV bus–voltage controlled bus– voltage magnitude and real power given.

Load flow solution can be represented as a linear problem, where loads and supplies are given in the form of current the system is described by a set of linear equations.

$$\bar{I}_i = \sum_{j=1}^{n} \bar{Y}_{ij} \bar{V}_j \ for i = 2,3,....,n \ [A,S,V] \quad (1)$$

where

$\bar{I}_i$ current at bus *i*,

$\bar{V}_j$ voltage at bus *j*,

$\bar{Y}_{ij}$ element of the bus admittance matrix,

n total number of buses in the system.

In reality, loads and supplies are given in form of active and reactive power

$$\bar{S}_i = P_i + Q_i i = \bar{V}_i \times \bar{I}^*_i \text{ for } i = 2,3,..n \text{ [VA;W,VAr,V,A]} \quad (2)$$

Newton-Raphson Method of load flow solution

Newton-Raphson method-iterative method for the solution of a set of nonlinear equations

Load flow equations

$$\bar{I}_i = \frac{P_i - Q_i i}{\bar{V}_i^*} = \sum_{j=1}^{n} \bar{Y}_{ij} \times \bar{V}_j \ for i = 2,3,...,n \qquad (3)$$

$$P_i - Q_i i = \bar{V}_i^* \times \sum_{j=1}^{n} \bar{Y}_{ij} \times \bar{V}_j \qquad (4)$$

$$P_i = \sum_{j=1}^{n} V_i \times V_j \times (G_{ij} \times \cos\delta_{ij} + B_{ij} \times \sin\delta_{ij}) \qquad (5)$$

$$Q_i = \sum_{j=1}^{n} V_i \times V_j \times (G_{ij} \times \sin\delta_{ij} - B_{ij} \times \cos\delta_{ij}) \quad (6)$$

Where

V_i, V_j bus voltage magnitudes (absolute values),

$\delta_{ij} = \delta_i - \delta_j$ difference of bus voltage phase angles,

G_{ij} real part of element $\bar{Y}_{ij}$ of the bus admittance matrix $[\bar{Y}]$,

B_{ij} imaginary part of element $\bar{Y}_{ij}$ of the bus admittance matrix $[\bar{Y}]$.

Active and reactive power differences for the estimated values are calculted

$$\Delta P_i^{(0)} = P_{iGiven} - P_i(V_1, V_2^{(0)},..., V_n^{(0)}, \delta_1, \delta_2^{(0)},...., \delta_n^{(0)}) \qquad (7)$$

$$\Delta Q_i^{(0)} = Q_{iGiven} - Q_i(V_1, V_2^{(0)},..., V_n^{(0)}, \delta_1, \delta_2^{(0)},..., \delta_n^{(0)}) \qquad (8)$$

Changes of voltage phase angles and magnitudes are calculated

$$\begin{bmatrix} [\Delta\delta^{(0)}] \\ [\Delta V^{(0)}] \end{bmatrix} = \left[J^{(0)}\right]^{-1} \times \begin{bmatrix} [\Delta P^{(0)}] \\ [\Delta Q^{(0)}] \end{bmatrix} \quad (9)$$

Table 1.Bus Parameters.

Bus	Type	Real Power P_i [MW]	Power Factor $\cos\varphi$ [–]
2	Load	40	0,95inductive
3	Load	40	0,95inductive
4	Load	40	0,95inductive
5	Load	50	0,95inductive
6	Load	40	0,95inductive
7	Load	45	0,95inductive
8	Load	40	0,95inductive
9	Load	40	0,95inductive
10	Load	45	0,95inductive
11	Supply	90	0,95inductive
12	Load	40	0,95inductive

Then supposed that load will grow in time, which will have influence on voltage and current relation in the network. Load growth of 1% per year. The estimation is done for periods of 10 and 20 years.
The Calculation of the load growth estimation :

1) Load Growth 1% per year after Ten Years

$$P_2' = P_2 * (1+0.01)^{10} = 40 * (1+0.01)^{10} = 44.18MW$$
$$P_3' = P_3 * (1+0.01)^{10} = 40 * (1+0.01)^{10} = 44.18MW$$
$$P_4' = P_4 * (1+0.01)^{10} = 40 * (1+0.01)^{10} = 44.18MW$$
$$P_5' = P_5 * (1+0.01)^{10} = 50 * (1+0.01)^{10} = 55.23MW$$
$$P_6' = P_6 * (1+0.01)^{10} = 40 * (1+0.01)^{10} = 44.18MW$$
$$P_7' = P_7 * (1+0.01)^{10} = 45 * (1+0.01)^{10} = 49.71MW$$
$$P_8' = P_8 * (1+0.01)^{10} = 40 * (1+0.01)^{10} = 44.18MW$$
$$P_9' = P_9 * (1+0.01)^{10} = 40 * (1+0.01)^{10} = 44.18MW$$
$$P_{10}' = P_{10} * (1+0.01)^{10} = 45 * (1+0.01)^{10} = 49.71MW$$
$$P_{10}' = P_{10} * (1+0.01)^{10} = 45 * (1+0.01)^{10} = 49.71MW$$
$$P_{12}' = P_{12} * (1+0.01)^{10} = 40 * (1+0.01)^{10} = 44.18MW$$

2) Load Growth 1% per year after Twenty years

$$P_2' = P_2 * (1+0.01)^{20} = 40 * (1+0.01)^{20} = 48.81\,MW$$
$$P_3' = P_3 * (1+0.01)^{20} = 40 * (1+0.01)^{20} = 48.81\,MW$$
$$P_4' = P_4 * (1+0.01)^{20} = 40 * (1+0.01)^{20} = 48.81\,MW$$
$$P_5' = P_5 * (1+0.01)^{20} = 50 * (1+0.01)^{20} = 61.00\,MW$$
$$P_6' = P_6 * (1+0.01)^{20} = 40 * (1+0.01)^{20} = 48.80\,MW$$
$$P_7' = P_7 * (1+0.01)^{20} = 45 * (1+0.01)^{20} = 54.91\,MW$$
$$P_8' = P_8 * (1+0.01)^{20} = 40 * (1+0.01)^{20} = 48.81\,MW$$
$$P_9' = P_9 * (1+0.01)^{20} = 40 * (1+0.01)^{20} = 48.81\,MW$$
$$P_{10}' = P_{10} * (1+0.01)^{20} = 45 * (1+0.01)^{20} = 54.71\,MW$$
$$P_{12}' = P_{12} * (1+0.01)^{20} = 40 * (1+0.01)^{20} = 48.81\,MW$$

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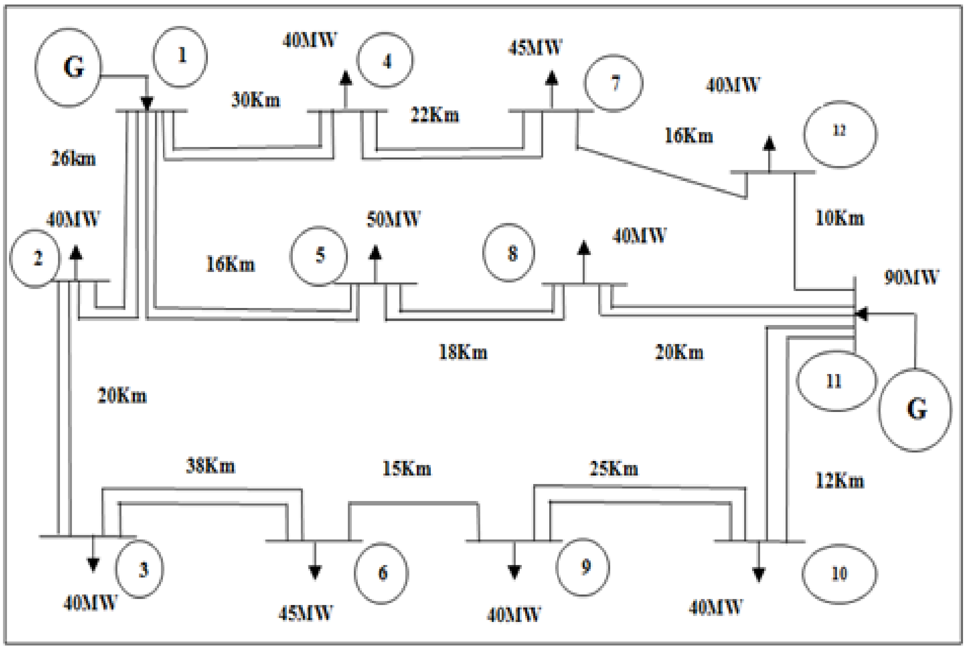

Figure 1: Enhanced Network 110K*V*, Thirteen Lines and twelve buses.

Table 2. Bus Parameters, after 10 years.

Bus	Type	Real Power P_i [MW]	Power Factor $\cos\varphi$ [–]
2	Load	44.18	0,95inductive
3	Load	44.18	0,95inductive
4	Load	44.18	0,95inductive
5	Load	55.23	0,95inductive
6	Load	44.18	0,95inductive
7	Load	49.71	0,95inductive
8	Load	44.18	0,95inductive
9	Load	44.18	0,95inductive
10	Load	49.71	0,95inductive
11	supply	90	0,95inductive
12	Load	44.18	0,95inductive

Table 3. Bus Parameters, after 20 years.

Bus	Type	Real Power P_i [MW]	Power Factor $\cos\varphi$ [–]
2	Load	48.81	0,95inductive
3	Load	48.81	0,95inductive
4	Load	48.81	0,95inductive
5	Load	61.00	0,95inductive
6	Load	48.81	0,95inductive
7	Load	54.91	0,95inductive
8	Load	48.81	0,95inductive
9	Load	48.81	0,95inductive
10	Load	54.91	0,95inductive
11	Supply	90	0,95inductive
12	Load	48.81	0,95inductive

The Simulation has been done by means of matlab Program, the results are shown in the following tables:

Table 4.Voltage Magnitudes and Phase Angles for Normal Operation 10 years.

Bus	Voltage Magnitude (phase-to-phase)		Voltage phase angle	
	[kV]	[% V_n]	[rad]	[deg]
1	110	100	0	0
2	105.2	95.66	-0.061	-3.513
3	102.9	93.55	-0.090	-5.168
4	107.9	98.11	-0.027	-1.538
5	108.4	98.51	-0.019	-1.104
6	101.5	92.31	-0.109	-6.242
7	106.3	96.64	-0.045	-2.613
8	107.2	97.43	-0.033	-1.886
9	102.1	92.80	-0.111	-6.341
10	104.4	94.90	-0.063	-3.607
11	106.1	96.45	-0.042	-2.409
12	105.1	95.56	-0.054	-3.117

Table 5. Line Currents for Normal Operation 10 years.

line	Bus		Current		Current Carrying Capacity
	i	*j*	[A]	[%]	[A]
1	1	2	763.73	65.95	1158
2	1	4	631.62	54.54	1158
3	1	5	750.72	64.83	1158
4	2	3	511.21	52.59	972
5	3	6	252.65	25.99	972
6	4	7	384.9	39.58	972
7	5	8	442.78	38.24	1158
8	6	9	17.433	5.447	320
9	7	12	101.92	31.85	320
10	8	11	195.63	20.13	972
11	9	10	272.14	23.50	1158
12	10	11	559.47	48.31	1158
13	11	12	152.87	26.40	579

Table 6. Line Flows for Normal Operation 10 years.

Line *i*–*j*		Real Power Flow	Reactive Power Flow
Bus *i*	Bus *j*	P_{ij} [MW]	Q_{ij} [MVAr]
1	2	136.33	49.79
1	4	113.75	38.69
1	5	133.25	51.62
2	1	-133.16	-41.53
2	3	88.97	27.01
3	2	-87.75	-25.11
3	6	43.57	10.59
4	1	-112.59	-36.05
4	7	68.41	21.53
5	1	-132.23	-48.99
5	8	77.00	30.84
6	3	-43.20	-11.13
6	9	-0.977	-3.39
7	4	-67.79	-21.11
7	12	18.08	4.77
8	5	-76.57	-30.27

8	11	32.39	15.75
9	6	0.987	2.43
9	10	-45.16	-16.95
10	9	45.33	18.76
10	11	-95.04	-35.10
11	8	-32.22	-16.59
11	10	95.83	36.77
11	12	26.38	9.40
12	7	-17.92	-5.04
12	11	-26.25	-9.48

From the results it is clear that after ten years the enhanced network under the required conditions,(bus Voltages and line loading are within the required ranges).

Table 7. Voltage Magnitudes and Phase Angles for Normal Operation 20 years.

Bus	Voltage Magnitude (phase-to-phase)		Voltage phase angle	
	[kV]	[% V_n]	[rad]	[deg]
1	110	100	0	0
2	104.7	95.19	-0.064	-3.680
3	102.2	92.87	-0.094	-5.368
4	107.5	97.74	-0.032	-1.857
5	107.2	97.42	-0.034	-1.945
6	100.7	91.53	-0.111	-6.362
7	105.5	95.93	-0.056	-3.236
8	105.8	96.17	-0.051	-2.908
9	101.8	92.54	-0.101	-5.793
10	102.6	93.27	-0.089	-5.127
11	104.5	94.99	-0.064	-3.645
12	103.6	94.21	-0.072	-4.142

Table 8. Line Currents for Normal Operation 20 years.

line	Bus		Current		Current Carrying capacity
	i	*j*	[A]	[%]	[A]
1	1	2	814.95	70.37	1158
2	1	4	758.59	65.51	1158
3	1	5	873.12	75.39	1158
4	2	3	534.53	54.99	972
5	3	6	246.55	25.36	972
6	4	7	484.54	49.85	972
7	5	8	529.03	45.68	1158
8	6	9	46.279	14.46	320
9	7	12	170.06	53.14	320
10	8	11	251.00	25.82	972
11	9	10	335.97	29.01	1158
12	10	11	659.84	56.98	1158
13	11	12	117.62	20.31	579

Table 9. Line Flows for Normal Operation 20 years.

Line *i–j*		Real Power Flow	Reactive Power Flow
Bus *i*	Bus *j*	P_{ij} [MW]	Q_{ij} [MVAr]
1	2	143.81	57.48
1	4	136.71	46.35
1	5	154.86	60.21
2	1	-140.19	-47.78
2	3	91.38	31.74
3	2	-90.05	-29.53
3	6	41.24	13.49
4	1	-135.03	-42.04
4	7	86.22	25.99
5	1	-152.78	-54.52
5	8	91.78	34.47
6	3	-40.88	-14.05
6	9	-7.93	-1.99
7	4	-85.24	-24.63
7	12	30.33	6.58
8	5	-91.18	-33.29
8	11	42.37	17.25
9	6	7.99	1.12
9	10	-56.81	-17.17
10	9	57.05	17.23
10	11	-111.96	-35.27
11	8	-42.07	-17.76
11	10	113.07	37.98
11	12	19.00	9.36
12	7	-29.88	-6.46
12	11	-18.93	-9.58

II. CONCLUSION

It can be concluded from the results of load flow solution for the enhanced network that the required conditions (bus voltages between 90 and 100% of nominal voltage, loading in all lines less than 80 % of line current carrying capacity) are fulfilled. It thus clear that the enhanced network is sufficiene for next twenty years (with an estimation of load growth by 1% per year) from the point of view of voltages as well as line loading for normal operation

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