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Power loss calculation of transmission line with consideration of voltage stability

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Abstract: This paper proposes a methodology for calculation of power loss in transmission line with consideration of voltage stability. Load bus voltage has been determined using continuation power flow methodology subjected to inequality constraints. Proposed Differential power loss method has been used to evaluate transmission losses. Obtained results on three standard IEEE systems have been compared with well stabilized methods.

Keywords: Load flow, Continuation power flow method, Differential power Loss Method, Transmission Loss, Voltage Stability.

1. Introduction

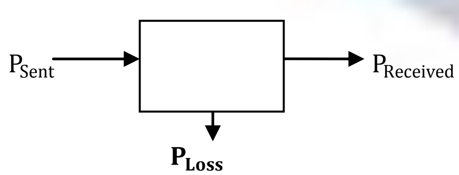
The flow of Electrical Power from one or more sources to loads consuming energy through available paths as commonly shown in a single line diagram. Electrical energy flow in a network divides among branches based on their respective impedance until a voltage balance reached in accordance to Kirchhoff's Laws. The flow will shift anytime the circuit configuration is changed or modified, generation is shifted or load requirements. This load change information are important for industrial plants and electric utility operators to ensure efficient operation.

Power flow analysis is the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling and exchange of power between utilities. The principal of power flow analysis is to find the magnitude and phase angle of voltage at each bus and the real and reactive power flowing in each transmission lines. Conventional techniques are used for solving the load flow problems are iterative. i.e. Continuation power flow method Newton-Raphson (NR) or the Gauss-Seidel(GS) methods [1]-[2]. This technique is difficult and takes a lot of times to perform by hand. For solving problem matlab programming is used. In paper, load flow problem is solved by Continuation power flow method.

The Losses in electrical power transmission network computed by means of Differential power loss method with consideration of voltage stability followed by Continuation power flow method algorithm. Voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating condition and after being subjected to a disturbance. In Differential Power loss method power loss expressed as difference between the transmitted power and received power [3] i.e.

$$\mathbf{P}_{loss} = \mathbf{P}_{Sent} - \mathbf{P}_{Received}$$

The relationship between the power sent, power received and associated losses in the power system is illustrated in fig below;



2. Problem Formulation

Continuation power flow method

The Jacobian matrix of power flow equations becomes singular at the voltage stability limit. Continuation power flow overcomes this problem i.e. reformulating the power flow equation so that they remain well conditioned at all possible loading conditions. These allow the solutions of the power flow problem for stable as well as unstable equilibrium points. It consists of prediction and correction steps. From a known base solution, a tangent predictor is used so as to estimate next solution for a specified pattern of load increase. The corrector step then determines the exact solution using Newton-Raphson technique employed by a conventional power flow. After that a new prediction is made for a specified increase in load based upon the new tangent vector. Then corrector step is applied. This process goes until critical point is reached. The critical point is the point where the tangent vector is zero.

Algorithm for Continuation power flow method [4]:

Let the power system consist of total n-number of buses. Bus 1 is a slack bus. Buses 2, 3....x+1 are x number of PV buses and the remaining Buses x+2, x+3.......n are PQ buses.

Step 1- Read line data and bus data of the given power system.

Step 2- Use line data formY_{bus} .

Step 3- Use the flat start for guess values for bus voltage magnitudes and phase angles. Set $V_i^{(0)}$= 1 p.u. for i = x+2, x+3......n and $\delta_i = 0$ radian for i = 2, 3 ....n.

Step4 - Calculate P_i (for the buses i = 2, 3......n) by using Equation:-

$$P_i = \sum_{k=1}^{n} |V_i||V_k||Y_{ik}|\cos(\delta_i - \delta_k + \gamma_{ik})$$

And Q_i (for the buses i = x+2, x+3,.......n) by using Equation:-

$$Q_i = \sum_{k=1}^{n} |V_i||V_k||Y_{ik}|\sin(\delta_i - \delta_k + \gamma_{ik})$$

While calculating these powers, use the most recently updated values of bus voltage magnitudes and phase angles.

Step 5- check $Q_i^{min} \leq Q_i \leq Q_i^{max}$ for PV buses. If Q_i is within the limits Go To Step 6 Else set $Q_i = Q_i^{min}$ or Q_i^{max} as the case and treat this i^{th} bus as PQ bus.Re-designate the bus number and return to step-1

Step 6- calculate power mismatches

$$\Delta P_i^r = P_i^{(s)} - P_i^{r(c)} \text{ for i=2, 3....., n}$$
$$\Delta Q_i^r = Q_i^{(s)} - Q_i^{r(c)} \text{ for i=x+2, x+3......, n}$$

Where the superscripts s denotes the specified value, r denotes the current iteration number and c denotes the calculated value. The subscript denotes the bus number.

Step 7- calculate the elements of the Jacobian Matrix.

Step 8- calculate the increment matrix as

$$\begin{bmatrix} \Delta\delta \\ \frac{\Delta|V|}{|V|} \end{bmatrix} = [J']^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}'$$

Step 9- Update voltage magnitudes and phase angles using the increments as:

$$|V|^{r+1} = |V|^r + \Delta|V|^r$$
$$\delta^{r+1} = \delta^r + \Delta\delta^r$$

Step10- check the convergence

$$\Delta|V_i| = |V_i|^{r+1} - |V_i|^r \leq \varepsilon \text{ for } i = x+2, x+3 \ldots .n$$
$$\Delta\delta_i = \delta_i^{r+1} - \delta_i^r \leq \varepsilon$$

Where, ε is the error specified. If all the convergence conditions are satisfied then go to step-11, otherwise go to step-3 and start the next iteration.

Step11- Using the specified and converged values of bus voltage and phase angles, calculate the injected power for the slack bus, and the injected reactive powers for the PV buses.

Step12- Perform Stage-2 calculation to determine line flows

Step13- End

Differential power loss method [6]:

The current flowing between the buses i and k can be written as

$I_{ik} = -Y_{ik}(V_i - V_k), \quad i \neq k$

Therefore the complex power leaving bus- i is given by

$P_i + jQ_i = V_i I_i^*$

Similarly the complex power entering bus- k is

$P_k + jQ_k = V_k I_k^*$

Therefore the I^2R loss in the line segment i-k is

$P_{loss,i-k} = P_i - P_k$

The real power flow over different lines is calculated. Which is the net difference between power generation and load. Finally we can compute the line I^2X drops in a similar fashion. This drop is given by

$$Q_{drop,i-k} = Q_i - Q_k$$

3. Results

The proposed differential power loss calculation method is tested on IEEE 30 bus, 14 bus and 5 bus systems. Losses for each line and the total losses of the system are calculated shown in tabulation form in TABLE 1, TABLE 2 and TABLE 3.

30 bus system:

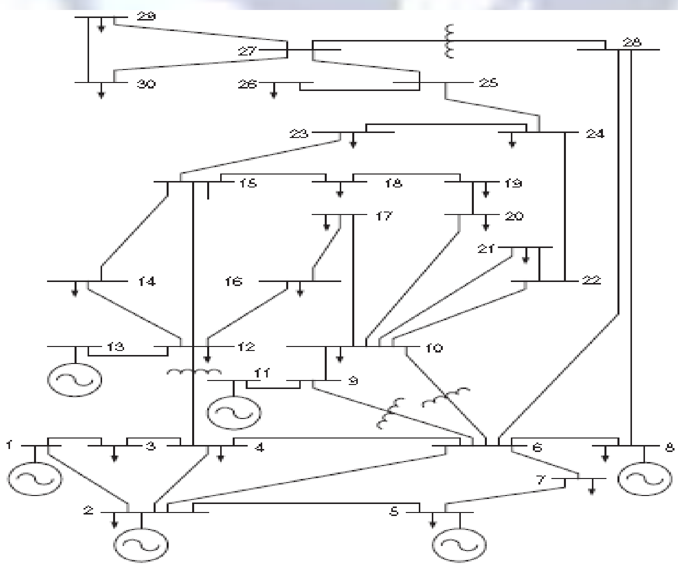


Fig.1: single line diagram of IEEE 30-bus test system
Initial data of 30 bus system taken from [5]

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TABLE 1

Power dispatched		Power received		Line
From (bus)	Amount (MW)	In (bus)	Amount (MW)	Loss (MW)
1	58.469	2	-57.873	0.595
1	40.789	3	-40.093	0.696
2	31.703	4	-31.169	0.534
2	45.322	5	-44.205	0.916
2	39.148	6	-38.318	0.831
3	37.693	4	-37.514	0.179
4	33.493	6	-33.363	0.130
4	27.590	12	-27.590	-0.000
5	0.205	7	-0.191	0.014
6	22.752	7	-22.609	0.143
6	10.554	8	-10.536	0.018
6	12.349	9	-12.349	0.000
6	10.634	10	-10.634	0.000
6	15.393	28	-15.348	0.045
8	0.536	28	-0.532	0.004
9	32.349	10	-32.349	0.000
10	8.370	20	-8.298	0.073
10	4.434	17	-4.427	0.007
10	16.376	21	-16.234	0.142
10	8.002	22	-7.933	0.069
11	20.000	9	-20.000	0.000
12	8.567	14	-8.458	0.110
12	19.545	15	-19.180	0.366
12	8.278	16	-8.134	0.143
13	20.000	12	-20.000	0.000
14	2.258	15	-2.236	0.022
15	6.710	18	-6.634	0.076
15	6.505	23	-6.407	0.099
16	4.634	17	-4.573	0.061
18	3.434	19	-3.416	0.018
20	6.098	19	-6.084	0.014
22	1.267	21	-1.266	0.000
22	6.666	24	-6.595	0.072
23	3.207	24	-3.150	0.056
24	1.045	25	-1.037	0.008
25	3.555	26	-3.500	0.055
27	2.528	25	-2.519	0.009
27	6.221	29	-6.113	0.108
27	7.131	30	-6.929	0.203
28	15.880	27	-15.880	0.000
29	3.713	30	-3.671	0.042
Total	613.205		607.347	5.858

14 bus system:

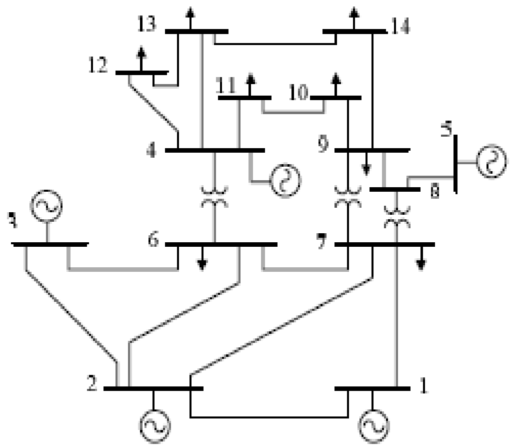

Figure.2: IEEE 14 Bus test system
Initial data of 5 bus system taken from [7]

TABLE 2

Power dispatched		Power received		Line
From (bus)	Amount (MW)	In (bus)	Amount (MW)	Loss(MW)
1	46.266	2	45.871	0.395
1	72.495	5	69.865	2.630
2	111.316	3	105.978	5.338
2	91.154	4	86.715	4.439
2	75.402	5	72.423	2.979
4	26.587	3	25.902	0.685
4	38.543	7	38.543	0
4	21.839	9	21.839	0
5	67.789	4	67.173	0.613
5	63.862	6	63.862	0
6	11.196	11	10.948	0.248
6	11.331	12	11.170	0.161
6	25.655	13	25.151	0.504
7	38.543	9	38.543	0
8	0	7	0	0
9	6.673	10	6.659	0.015
9	12.408	14	12.217	0.191
11	6.048	10	5.941	0.107
12	2.630	13	2.607	0.023
13	8.858	14	8.643	0.215
Total	738.592		720.05	18.541

5 bus system:

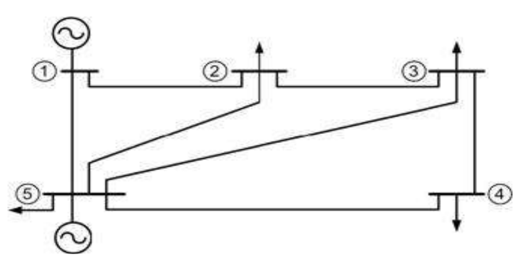

Figure 3: 5 Bus test system, Initial data of 5 bus system taken from [6]

TABLE 3

Power dispatched		Power received		Line
From (bus)	Amount (MW)	In (bus)	Amount (MW)	Loss(MW)
1	101.039	2	98.649	2.390
2	17.617	3	17.488	.129
3	.798	4	.789	.009
1	25.556	5	25.230	.326
5	15.152	2	14.968	.184
5	18.621	3	18.309	.312
5	15.457	4	15.211	.245
Total	194.24		190.644	3.596

4. Conclusions

In this paper, a differential power loss method has been successfully applied on three standard IEEE systems to calculate power loss in transmission system. Obtained results from this method are accurate and verified with well stabilized methods.

Reference

[1]. W. F. Tinney, C. E. Hart, "Power Flow Solution by Newton's Method, " IEEE Transactions on Power Apparatus and systems , Vol. PAS-86, pp. 1449-1460, November 1967.
[2]. W. F. Tinney, C. E. Hart, "Power Flow Solution by Newton's Method, "IEEE TRANS. POWER APPARATUS AND SYSTEMS, Vol. PAS-86, pp. 1449-1460, November 1967.
[3]. M. C. Anumaka, Analysis Of Technical Losses In Electrical Power System (Nigerian 330kv Network As A Case Study), Volumes/Vol12Issue2/IJRRAS_12_2_20.pdf.
[4]. N.V RAMANA, Power System Analysis, pearson publications.
[5]. A.A. Abou El Elaa, M.A. Abidob, S.R. Speaa, Differential evolution algorithm for optimal reactive power dispatch.
[6]. NPTEL online-IIT Kanpur, power system analysis chapter-4 section 7.
[7]. Searching in Google data sheets for IEEE 14 bus system 19 Appendix pdf.