Research Article

APPLICATION OF TOPOLOGICAL TECHNIQUE METHODS IN POWER FLOW COMPUTATION OF RADIAL DISTRIBUTION NETWORKS WITHOUT ITERATON AND WITH ITERATED

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Abstract: In computing power flow in a radial distribution network system, it is rather difficult to do. Because it is not easy to reach a convergence point. In another case, the loop or ring distribution network system is easy to reach a convergence point. By using topological engineering methods, power flow computation in a radial distribution network system can be done with the help of computer software. The computation that will be carried out is the amount of voltage, voltage drop, current and power on the conductor and the losses that occur in the network. The calculation is done in two ways, namely iteratively and without iteration. From the two calculations, it can be shown that the calculation without iteration is good enough to be used in calculating the power flow of the radial distribution network.

Keywords: ***Radial distribution network system, loop or ring distribution network system, convergence point, topological engineering method, without iteration and iteration***

1. Introduction

At this time the radial distribution network is the most widely used because it has a simple construction and is cheap. Its use is especially in areas with low load densities. This distribution network originates from a substation or directly from a power plant, then spreads to distribution substations or directly to consumers who require large power, such as industry. The reliability of this system is low and has a large voltage drop, especially for end-of-line loads.

This radial form network system has a weakness, which is that it is only connected to a resource through one road, so the continuity of its service is not guaranteed, because if there is a disruption in the main feeder closest to the resource, all services will be cut off until the disturbance can be resolved. 1]. The problem faced by this radial distribution network is how to properly distribute power (quantity and quality) at a certain time or in the future. Therefore it is necessary to have a proper analysis, namely power flow analysis to determine the voltage, current, power and losses in normal operation [2]. The calculation of the power flow of the radial distribution network that is discussed uses topological engineering methods [3]. In this paper, we present the state of the art of calculating the power flow of a radial distribution network. This paper differs from other writings in terms of calculating the power flow of the radial distribution network. Previously, the calculation of the radial distribution network power flow to calculate the injection current in a system where the nodes are not simplified in the form of a topological matrix [4]. Whereas in this paper the calculation of injection currents in a system where the nodes can be simplified in the form of a topological matrix, making calculations easier and faster. The object of the calculation is to find out: 1. Voltage for each node of the radial distribution network system, 2. Current and power flowing in each branch of the network, and 3. Losses for each branch of the distribution network.

2. Research Methods

2.1. Study of literature

2.1.1. Topological Engineering

Topology technique is a technique of analyzing electrical networks that describes network elements as line segments called branches and connecting points as nodes, all of which are drawn in a graph of the network [3].

The use of medium and low voltage distribution networks allows simplification of the problem which aims to simplify calculations, namely by including the capacity effect as part of the injection current of each node.

a. Some Definitions in Topological Techniques

(1) Branch, a line segment that describes a network element connected between two nodes.
(2) Node, the point located at each end of the branch, and describes a connection point.
(3) Oriented graph, which is a graph in which the nodes and branches have been numbered and have a flow direction.
(4) Subgraph, the branches and nodes of the graph.
(5) Loop, a collection of branches and nodes in a graph that form a closed path.
(6) Tree, a simple graph where there are no branches forming a loop. The radial network is a tree.

b. Network Representation

The representation as a 4 pole network when the channel capacitance is not neglected, as in Figure 1 (a), and Figure 1 (b) is the network topology for Figure 1 (a). Such channels are represented as series of nominal phi (p) [5].

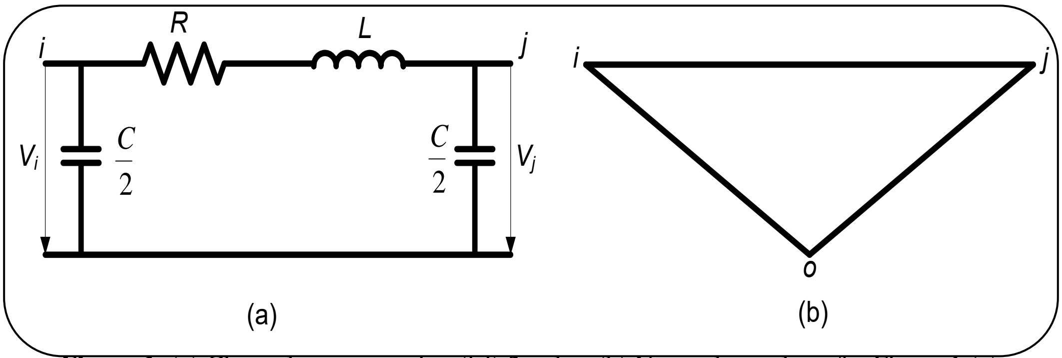

Figure 1. (a) Channel representation (i-j) 2 poles, (b) Network topology for Figure 1 (a).

Represent it as a 2-pole network when the effect of channel capacitance is neglected, as shown in Figure 2 (a), and Figure 2 (b) is the network topology for Figure 2 (a).

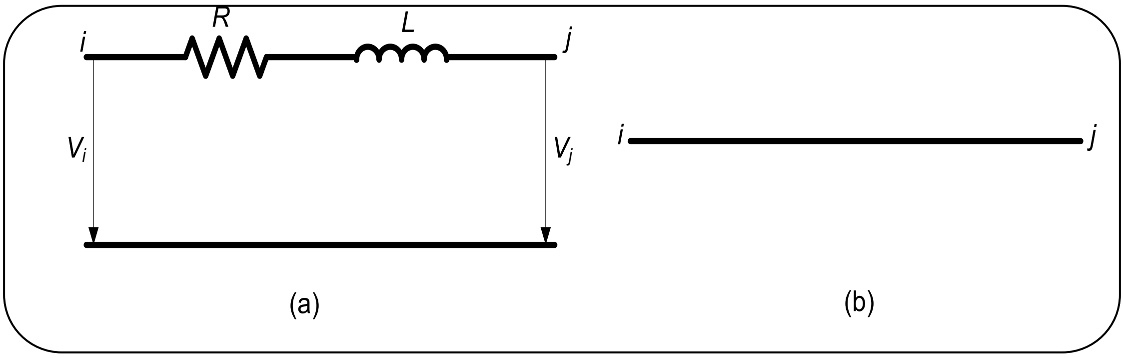

Figure 2. (a) Channel representation (i-j) 2 poles, (b) Network topology for Figure 2 (a).

c. Radial Network Topology

Compared with other network structures, radial networks have some special properties that can be utilized to facilitate problem solving [3-6], viz

(1) On a radial network there is only one resource node, and the other nodes are load nodes.
(2) Positive injection currents are found at the resource node, while at other nodes, injection currents are negative.
(3) In a radial network there is a relationship

$b = n-1$ (1) where b is the number of branches, and n is the number of nodes.

While for example, a radial network with 5 nodes and 4 topological branches is in Figure 3. The order of the topological matrix, the number of nodes n (rows) and b branches (columns). The formation is based on

(1) Element has value 0 if branch j and node i are not related.

(2) Element is worth +1 when branch j is related to node i and the direction of flow is leaving node i.

(3) Element is worth -1 if branch j is related to node i and the direction of flow to node i.

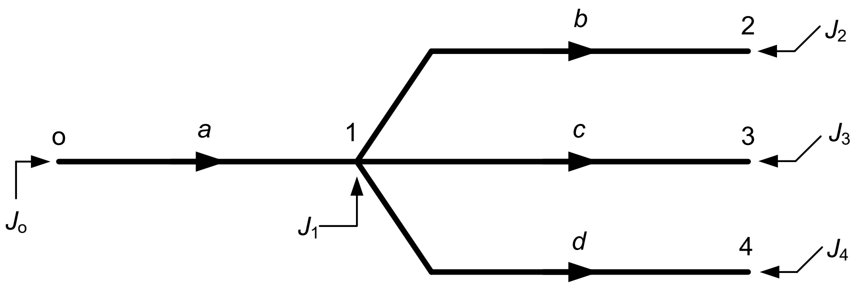

Figure 3.Radial network topology with n = 5 and b = 4.

From Figure 3, it is known that Jo = Ia. So the network is depicted as in Figure 4.

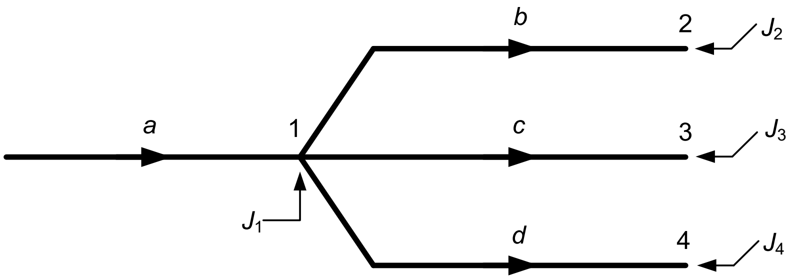

Figure 4. Simplification of the radial network topology.

Then the radial network topology matrix can be written as Figure 5 below

$$[TR] = \begin{array}{c|cccc} n \backslash b & a & b & c & d \\ \hline 1 & -1 & 1 & 1 & 1 \\ 2 & 0 & -1 & 0 & 0 \\ 3 & 0 & 0 & -1 & 0 \\ 4 & 0 & 0 & 0 & -1 \end{array}$$

Figure 5. The radial network topology matrix from Figure 4.

2.1.2. Network Characteristics Equations

Internal characteristics are network characteristics based on the conditions occurring in the branch [6-8]. The variables are V (voltage drop across the branch) and I (branch current).The relationship between the two is

$$[V] = [z][I] \qquad (2)$$

where [z] is the branch impedance matrix

External characteristics are network characteristics based on what occurs in nodes. The variables are V (voltage at the node) and J (injection current). The relationship between the two is carried out through their internal characteristics, namely:

$$[J] = [TR]\ [I] \qquad (3) \qquad [V] = [TR]^t\ [V] \qquad (4)$$

where [TR] t is the transpose of the topological matrix.

So that the relationship between the injection current and the voltage for each node is

$$[J] = [TR]\,[y]\,[V] = [TR][y][TR]^t[V]$$
$$[J] = [Y]\,[V] \tag{5}$$

where [Y] is the Y_{bus} matrix

2.1.3. Injection Current Equation

In radial networks, the injection current at the load node is negative [3]. Thus obtained

$$K_i = -J_i \tag{6}$$

where K_i is the negative injection current at node i.

The injection current for the load node can be written

$$J_i = \frac{-Pb_i + jQb_i}{V_i^*}$$

Or

$$K_i = \frac{Pb_i - jQb_i}{V_i^*} \tag{7}$$

Thus the magnitude of the negative injection current at node i can be calculated as the absolute value of Equation (7), i.e.

$$\left|K_i\right| = \frac{\sqrt{(Pb_i)^2 + (Qb_i)^2}}{V_i^*} \tag{8}$$

By substituting Equation (3) to Equation (6), then

$$[K] = -[TR]\;[I]$$
$$[I] = -[TR]^{-1}\;[K] = [A]\;[K] \tag{9}$$

where $[A] = [TR]^{-1}$ is the inverse matrix radial network topology.

Matrix A can be derived directly from network oriented graph based on the following conditions

(1) Rows represent branches and columns represent nodes.
(2) Element has a value of +1 if the current reaching node n passes through the branch to b.
(3) Element has value 0 if the second condition above is not fulfilled.

Then the direct derivation of matrix A based on Figure 4 is as shown in Figure 6 below

[A] =

b \ n	1	2	3	4
a	1	1	1	1
b	0	1	0	0
c	0	0	1	0
d	0	0	0	1

Figure 6. Direct derivation of matrix A based on Figure 4.

2.1.4. Voltage Drop On Radial Network

In radial networks, the voltage drop is calculated for each branch and each node with respect to node 0 (total stress drop) [9-10].

Equation (9) is substituted for Equation (2), obtained

$$[V] = [z][A][K] \tag{10}$$

Meanwhile, the voltage drop between each node and node 0 is

$$[U] = [A]^t [V] \tag{11}$$

Equation (10) is substituted for Equation (11), obtained

$$[U] = [Z] [K] \tag{12}$$

$$[Z] = [A]^t [z][A] \tag{13}$$

where [Z] is the radial network Z_{bus} matrix.

And the voltage for each node can be calculated with the following equation

$$V_i = V_0 - U_i \tag{14}$$

where V_0 is the voltage at node 0 (power source).

2.1.5. Power Equation

The general power equation for a network is written [11-13]

$$S_{i,\ j} = P_{i,\ j} + jQ_{i,\ j} = V_i I \tag{15}$$

$$S_{j,\ i} = P_{j,\ i} + jQ_{j,\ i} = -(V_j)I \tag{16}$$

Where $S_{i,j}$ is the power flowing from node i to node j, V_i is the voltage at node i, I = $I_{i,j}$ is the current flowing from node i to node j, $S_{j,i}$ is the power flowing from node j to node i, V_i is the voltage at node j, and - (I) = $I_{j,i}$is the current flowing from node j to node i

The algebraic sum of Equation (15) and Equation (16) is the channel power losses, i.e.

$$\begin{aligned} S_{i,j} + S_{j,\ i} &= V_i I - V_j I \\ &= V_{i,\ j} I = z_{i,\ j} I.\ I \\ &= (R_{i,\ j} + jX_{i,\ j}) I^2 \end{aligned} \tag{17}$$

Or

$$p + jq = R_{i,\ j} I^2 + j(X_{i,\ j} I^2) \tag{18}$$

Where $R_{i,\ j}$ is the resistance of channel ij and $X_{i,\ j}$ r channel reactance ij.

The equation matrix is written as follows

$$[p] = [R][I^2] \text{ dan } [q] = [X][I^2] \tag{19}$$

Seems like

$$Pb_i - jQb_i$$

$$U_i = Z_i . K_i \text{ dan } K_i = V_i$$

Mean

$$\Delta U_i = Z_i . \frac{Pb_i - jQb_i}{V_i^*} \tag{20}$$

So,

$$V_i = V_0 - Z_i . \frac{Pb_i - jQb_i}{V_i^*} \tag{21}$$

From Equation (21), it can be seen that there are two variables, V_i, namely V_i, the left side and V_i the right side conjugate. So to get the price, V_i the voltage assumption must be made.

Calculations are made for the magnitude. The line capacitance values calculated for the reactive load and the branch impedance can be calculated by the following equation

$$z = \left| z \right| (\cos \varphi + j \sin \varphi) \\ = r + jx \tag{22}$$

$$K_i = \frac{\sqrt{(Pb_i)^2 + [Qb_i - \sum_{j \varepsilon \alpha i} \left(\frac{y'_{i,j}}{2} \right) (V_i)^2]^2}}{V_i} \tag{23}$$

2.1.6. Iteration Radial Network Power Flow Calculation Algorithm

The stages of the calculation process are

(1) The initial stress of node i is assumed to be 1 per unit (1 pu), or V_i = 1 pu.

(2) Form a matrix A.

(3) Forming a Zbus matrix, namely $[Z] = [A]^t [z][A]$.

(4) Calculate the injection current at node i with the equation

$$K_i = \frac{\sqrt{(Pb_i)^2 + [Qb_i - \sum_{j \varepsilon \alpha i} \left(\frac{y'_{i,j}}{2} \right) (V_i)^2]^2}}{V_i}$$

(5) Calculate the total voltage drop ie $[U] = [Z].[K]$.

(6) Calculate the voltage at node iie $V_i = V_0 - U_i$.

(7) Checking whether it has converged to the precision index, namely $V_{ik} - V_{ik-1}$

The iteration index k and the precision index. If the 7th stage is not fulfilled, then the calculation process is repeated starting from the 4th stage, and previously $V_{ik} - V_{ik-1}$ determined that it continues until the 7th stage is fulfilled.

After the iteration is complete, the process is continued, namely

(1) Calculate the current ie $[I] = [A]\ [K]$.

(2) Calculating the voltage drop for each branch, namely $[V] = [z][I]$.

(3) Calculating the power flowing in each branch, namely

$$S_{i,j} = V_i I_\alpha \qquad S_{j,i} = V_j I_\alpha$$

(4) Calculating the power losses for each branch, namely $\Delta S = S_{i,j} + S_{j,i}$.

2.2 Network images and data

The radial type network image is shown in Figure 7.Impedance data for each branch is as in Table 1 and the load data for each node is as shown in Table 2.With basic kVA = 100 kVA, base voltage = 12 kV

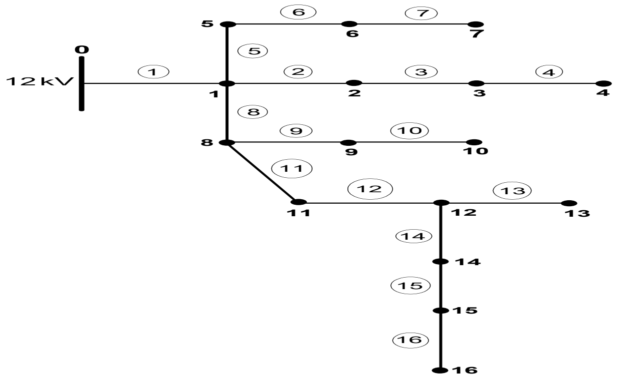

Figure 7. One line diagram of a radial type distribution network.

Caption :

j : J branch

Table 1. Impedance data for each branch.

Node		Branch	R	X
i	j		(Ohm)	(Ohm)
0	1	1	0,012201	0,001673
1	2	2	0,012510	0,001472
2	3	3	0,021410	0,015054
3	4	4	0,125435	0,102188
1	5	5	0,273861	0,221886
5	6	6	0,240225	0,228364
6	7	7	0,252330	0,235446
1	8	8	0,088300	0,074550
8	9	9	0,234900	0,223531
9	10	10	0,154600	0,147101
8	11	11	0,090550	0,093663
11	12	12	0,064900	0,025651
12	13	13	0,235325	0,215013
12	14	14	0,371590	0,127380
14	15	15	0,284848	0,190203
15	16	16	0,281060	0,145253

Table 2. Load data for each node.

Node	Pb (kW)	Qb (kVAR)
0		
1	2900,00	1120,13
2	143,72	78,20
3	184,75	105,95
4	512,00	134,00
5	211,00	123,00
6	79,60	49,25
7	63,23	31,35
8	107,78	51,78
9	145,25	87,21
10	117,50	68,46
11	98,92	61,18
12	74,50	35,92
13	87,70	44,54
14	64,26	39,48
15	92,18	54,48
16	81,25	52,87

3. Calculation and Analysis Results

3.1. The calculation results

The calculation results at the nodes without iterations: negative injection currents and voltages as in Table 3.Calculation results for branches without iterations: current, voltage drop, power flow and power losses are as in Table 4.The nominal voltage on the load side is 90% with take the average price of 95% or 0.95. The stress on the radial network is assumed to be evenly distributed.

Table 3. Calculation results at nodes without iteration: injection current negative and voltage.

NODE	NEGATIVE INJECTION CURRENT (AMPERE)	VOLTAGE (kV)
1	259.1940	11.9941
2	13.6426	11.9931
3	17.7605	11.9914
4	44.1629	11.9839
5	20.3842	11.9815
6	7.8155	11.9767
7	5.8937	11.9746
8	9.9777	11.9840
9	14.1475	11.9753
10	11.3582	11.9728
11	9.7108	11.9774
12	6.9069	11.9746
13	8.2161	11.9718
14	6.3033	11.9649
15	8.9537	11.9588
16	8.1077	11.9561

Table 4. Calculation results for branches without iteration: current, voltage drop, flow power and power losses.

BRANCH	CURRENT (AMPERE)	VOLTAGE DROP (kV)	LOAD FLOW (kVA)	POWER LOSSES (kVA)
1	453.3555	0.0056	5430.4255	2.6520
2	75.5660	0.0010	906.7920	0.5185
3	61.9234	0.0016	743.0809	0.5304
4	44.1629	0.0071	529.9527	0.7100
5	34.0934	0.0120	409.1211	0.6303
6	13.7092	0.0045	164.5107	0.3189
7	5.8937	0.0020	70.7249	0.1497
8	83.6821	0.0097	1004.1847	1.3402
9	25.5057	0.0083	306.0680	0.6301
10	11.3582	0.0024	136.2985	0.3095
11	48.1987	0.0063	578.3839	1.0896
12	38.4878	0.0027	461.8538	0.9786
13	8.2161	0.0026	98.5936	0.2315
14	23.3648	0.0092	280.3773	0.8190
15	17.0614	0.0058	204.7373	0.7027
16	8.1077	0.0026	97.2928	0.3557

The calculation results at the node by iteration: negative injection currents and voltages are as in Table 5.Calculation results in the iterative branches: current, voltage drop, power flow and power losses as in Table 6

Table 5. The results of the iteration of the nodes: current negative injection and voltage.

NODE	NEGATIVE INJECTION CURRENT (AMPERE)	VOLTAGE (kV)
1	259.1876	11.9944
2	13.6422	11.9935
3	17.7599	11.9919
4	44.1599	11.9847
5	20.3826	11.9824
6	7.8147	11.9779
7	5.8931	11.9759
8	9.9771	11.9848
9	14.1460	11.9765
10	11.3569	11.9741
11	9.7099	11.9785
12	6.9062	11.9758
13	8.2152	11.9732
14	6.3024	11.9667
15	8.9522	11.9609
16	8.1062	11.9583

Table 6. Calculation results in iterated branches: current, voltage drop, flow power and power losses.

BRANCH	CURRENT (AMPERE)	VOLTAGE DROP (kV)	LOAD FLOW (kVA)	POWER LOSSES (kVA)
1	452.5122	0.0056	5430.1463	2.5193
2	75.5620	0.0010	906.7442	0.4925
3	61.9198	0.0016	743.0378	0.5038
4	44.1599	0.0071	529.9192	0.6744
5	34.0905	0.0120	409.0856	0.5987
6	13.7078	0.0045	164.4941	0.3029
7	5.8931	0.0020	70.7174	0.1422
8	83.6721	0.0097	1004.0649	1.2731
9	25.5029	0.0083	306.0350	0.5985
10	11.3569	0.0024	136.2830	0.2940
11	48.1921	0.0063	578.3051	1.0350
12	38.4822	0.0027	461.7859	0.9295
13	8.2152	0.0026	98.5820	0.2199
14	23.3608	0.0092	280.3298	0.7780
15	17.0584	0.0058	204.7010	0.6674
16	8.1062	0.0026	97.2750	0.3379

Table 7 comparison of the results of the calculation of the voltage without iteration and iteration at each node, Table 8 comparison of the results of the calculation of power without iteration and iteration in each branch, Table 9 the comparison of the results of the calculation of the current without iteration and iteratively in each branch.

Table 7. Comparison of the results of stress calculations without iteration and iteratively on each node.

NODE	WITHOUT VOLTAGE ITERATION (kV)	ITERATION VOLATGE (kV)	COMPARISON (%)
1	11.9941	11.9944	0.0025
2	11.9931	11.9935	0.0033
3	11.9914	11.9919	0.0042
4	11.9839	11.9847	0.0067
5	11.9815	11.9824	0.0075
6	11.9767	11.9779	0.0100
7	11.9746	11.9759	0.0109
8	11.9840	11.9848	0.0067
9	11.9753	11.9765	0.0100
10	11.9728	11.9765	0.0309
11	11.9774	11.9785	0.0092
12	11.9746	11.9758	0.0100
13	11.9732	11.9718	0.0117
14	11.9667	11.9649	0.0151
15	11.9588	11.9609	0.0176
16	11.9561	11.9583	0.0184
RELATIVE ERROR PERSENTAGE AVERAGE :			0.0109

Table 8. Comparison of power calculation results without iteration and iteratively on each branch

BRANCH	WITHOUT POWER ITERATION (kVA)	ITERATION POWER (kVA)	COMPARISON (%)
1	5430.4255	5430.1463	0.0051
2	906.7920	906.7442	0.0053
3	743.0809	743.0378	0.0058
4	529.9547	529.9192	0.0067
5	409.1211	409.0856	0.0087
6	164.5107	164.4941	0.0101
7	70.7249	70.7174	0.0106
8	1004.1847	1004.0649	0.0119
9	306.0680	306.0350	0.0108
10	136.2985	136.2830	0.0114
11	578.3839	578.3051	0.0136
12	461.8538	461.7859	0.0147
13	98.5936	98.5820	0.0118
14	280.3773	280.3298	0.0169
15	204.8373	204.7010	0.0666
16	97.2928	97.2750	0.0183
RELATIVE ERROR PERSENTAGE AVERAGE :			0.0143

Table 9. Comparison of current calculation results without iteration and iteration on each branch.

BRANCH	CURRENT WITHOUT ITERATION (AMPERE)	ITERATION CURRENT (AMPERE)	COMPARISON (%)
1	452.5355	452.5122	0.0052
2	75.5660	75.5620	0.0053
3	61.9234	61.9198	0.0058
4	44.1629	44.1599	0.0068
5	34.0934	34.0905	0.0085
6	13.7092	13.7078	0.0102
7	5.8937	5.8931	0.0102
8	83.6821	83.6721	0.0119
9	25.5057	25.5029	0.0108
10	11.3582	11.3569	0.0115
11	48.1987	48.1921	0.0137
12	38.4878	38.4822	0.0146
13	8.2161	8.2152	0.0110
14	23.3648	23.3608	0.0171
15	17.0614	17.0584	0.0176
16	8.1077	8.1062	0.0185
RELATIVE ERROR PERSENTAGE AVERAGE :			0.0112

3.2. Analysis

The calculation steps without iteration are almost the same as the iteration steps. The difference is in the voltage assumption. Calculations without iteration where the nominal stress on the load side of the quality of the stress is assumed for the medium voltage network at 90% by taking the average price of 95% or 0.95 while for the low voltage network it is set at 95% by taking the average price of 97, 5% or 0.975. The taking of the average nominal voltage on the load side for medium voltage networks can be seen as in Figure 8.

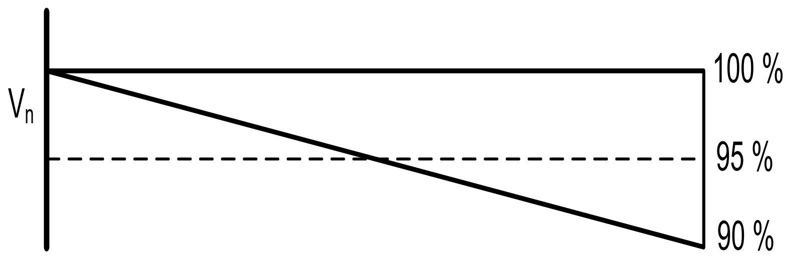

Figure 8. Diagram of the stress assumption on the load side for medium voltage network.

From Figure 8 above the voltage on the load side is V_b = 95% V_n = 0.95 V_n. The stress on the radial network is assumed to be evenly distributed along the network.

4. Conclusion

The use of topological engineering methods for calculating the power flow of radial distribution networks is a contribution in solving the problem of power flow distribution networks. The calculation process is carried out without simplifying the topological structure or the power flow equation so that the results will be more accurate. It uses less memory than other methods, because the formation of the inverse topology matrix can be formed directly without inverse matrix A and the branch impedance matrix can be stored as a column matrix. The results of the calculation of power flow with the topological engineering method using the iterative process are more accurate than the iterative calculation, but the difference between the two methods is quite small (below 5%), so the use of calculations without iteration is still acceptable and will save calculation time and usage. memory on the computer.

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