



LOAD FLOW SOLUTION OF UNBALANCED RADIAL DISTRIBUTION SYSTEMS

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ABSTRACT

This paper presents a simple three phase load flow method to solve three-phase unbalanced radial distribution system (RDS). It solves a simple algebraic recursive expression of voltage magnitude, and all the data are stored in vector form. The algorithm uses basic principles of circuit theory and can be easily understood. Mutual coupling between the phases has been included in the mathematical model. The proposed algorithm has been tested with several unbalanced distribution networks and the result of an unbalanced RDS is presented in the article. The application of the proposed method is also extended to find optimum location for reactive power compensation and network reconfiguration for planning and day-to-day operation of distribution networks.

Index Terms: Radial Distribution Networks, Load Flow, Circuit Model, Three-Phase Four-Wire, Unbalance.

NOMENCLATURE

The three phases, neutral and ground are referred to with the superscripts a , b , c , n , and g , respectively. p and q The subscripts p and q in the paper denotes the buses of three phase system.

$V_p^{ag} = V_p^a$	Voltage of phase a at bus p with respect to ground.
ΔV_p^{ab}	Voltage drop between two phases a and b at bus p .
ΔV_{pq}^a	Voltage drop between buses p and q in phase a .
ze_{pq}^{aa}	Self-impedance between buses p and q in phase a .
ze_{pq}^{ab}	Mutual impedance between phases a and b between buses p and q
PL_q^a, QL_q^a and SL_q^a	Real, reactive and complex power loads at phase a at q th bus.
IL_q^{phase}	Complex load current at phase (a , b , and c) at q th bus.
IC_q^{phase}	Charging current at phase (a , b , and c) at q th bus.
I_{pq}^{phase}	Complex current at phase (a , b , and c) between buses p and q .
LP_{pq}^{phase}	Real power loss in the line between bus p and q in phase (a , b , and c).
LQ_{pq}^{phase}	Reactive power loss in the line between bus p and q in phase (a , b , and c).
LS_{pq}^{phase}	equals $LP_{pq}^{phase} + jQL_{pq}^{phase}$
N	Total number of buses vector beyond the line between bus p and q
IE	Receiving end bus corresponding to the N vector



INTRODUCTION

Load flow technique is very important tool for analysis of power systems and used in operational as well as planning stages. Certain applications, particularly in distribution automation and optimization require repeated load flow solutions. As the power distribution networks become more and more complex, there is a higher demand for efficient and reliable system operation. Consequently, the most important system analysis tool, load flow studies, must have the capability to handle various system configurations with adequate accuracy and speed.

In many cases, it is observed that the radial distribution systems are unbalanced because of single-phase, two-phase and three-phase loads. Thus, load flow solution for unbalanced case and, hence special treatment is required for solving such networks.

Due to the high R/X ratios and unbalanced operation in distribution systems, the Newton-Raphson and ordinary Fast Decoupled Load Flow method may provide inaccurate results and may not be converged. Therefore, conventional load flow methods cannot be directly applied to distribution systems. In many cases, the radial distribution systems include untransposed lines which are unbalanced because of single phase, two phase and three phase loads. Thus, load flow analysis of balanced radial distribution systems [1-3] will be inefficient to solve the unbalanced cases and the distribution systems need to be analyzed on a three phase basis instead of single phase basis.

There have been a lot of interests in the area of three phase distribution load flows. A fast decoupled power flow method has been proposed in [4]. This method orders the laterals instead of buses into layers, thus reducing the problem size to the number of laterals. Using of lateral variables instead of bus variables makes this method more efficient for a given system topology, but it may add some difficulties if the network topology is changed regularly, which is common in distribution systems because of switching operations. In [5], a method for solving unbalanced radial distribution systems based on the Newton-Raphson method has been proposed. Thukaram *et al.* [6] have proposed a method for solving three-phase radial distribution networks. This method uses the forward and backward propagation to calculate branch currents and bus voltages. A three-phase fast decoupled power flow method has been

proposed in [6]. This method uses traditional Newton-Raphson algorithm in a rectangular coordinate system.

In recent years the three-phase current injection method (TCIM) has been proposed [8]. TCIM is based on the current injection equations written in rectangular coordinates and is a full Newton method. As such, it presents quadratic convergence properties and convergence is obtained for all but some extremely ill-conditioned cases. Further TCIM developments led to the representation of control devices [9], [10]. Miu *et al.*, [11] have also proposed method for solving three-phase radial distribution networks. However, methods proposed by researchers reviewed above are very cumbersome and large computation time is required.

A fast decoupled G-matrix method for power flow, based on equivalent current injections, has been proposed in [12]. This method uses a constant Jacobian matrix which needs to be inverted only once. However, the Jacobian matrix is formed by omitting the reactance of the distribution lines with the assumption that $R \gg X$; and fails if $X > R$. In [14], a method has been suggested for three phase power flow analysis in distribution networks by combining the implicit Z-bus method [13] and the Gauss-Seidel method. This method uses fractional factorization of Y-bus matrix. Thus, large computational time is necessary for this method. The Network Topology method uses two matrices, viz. bus injection to branch current (BIBC) and branch-current to bus-voltage (BCBV) matrices, to find out the solution [15]. The Forward-Backward Substitution [16] and Ladder Network theory [17] based on approaches trace the network to and fro from its load end to source end.

In this article, a simple algorithm is developed which is based on basic systems analysis method and circuit theory. The purpose of this paper is to develop a new computation model for radial distribution network, which requires lesser computer memory and is computationally fast. The proposed method involves only recursive algebraic equations to be solved to get the following information:

- Status of the feeder line, and overloading of the conductor and feeder line currents.
- Whether the system can maintain adequate voltage level for the remote loads.

- The line losses in each segment.
- It can also suggest the necessity of re-routing or network reconfiguration for the existing distribution network.

The algorithm has been developed considering that all loads draw constant power. However, the algorithm can easily accommodate composite load modeling, if the composition of load is known. The algorithm has good convergence property for practical radial distribution networks.

SOLUTION METHODOLOGY

For the analysis of power transmission line, two fundamental assumptions are made, namely:

- Three-phase currents are balanced.
- Transposition of the conductors to achieve balanced line parameters.

However, distribution systems do not lend themselves to either of the two assumptions. Because of the dominance of single-phase loads, the assumption of balanced three-phase currents

is not applicable. Distribution lines are seldom transposed, nor can it be assumed that the conductor configuration is an equilateral triangle. When these two assumptions are invalid, it is necessary to introduce a more accurate method of calculating the line impedance.

A general representation of a distribution system with N conductors can be formulated by resorting to the Carson's equations [18], leading to a N×N primitive impedance matrix. For most application, the primitive impedance matrices containing the self and mutual impedance of the each branch need to be reduced to the same dimension. A convenient representation can be formulated as a 3×3 matrix in the phase frame, consisting of the self and mutual equivalent impedances for the three phases. The standard method used to form this matrix is the Kron reduction, based on the Kirchoff's laws. For instance a four-wire grounded wye overhead distribution line shown in fig. 1 results in a 4×4 impedance matrix. The corresponding equations are

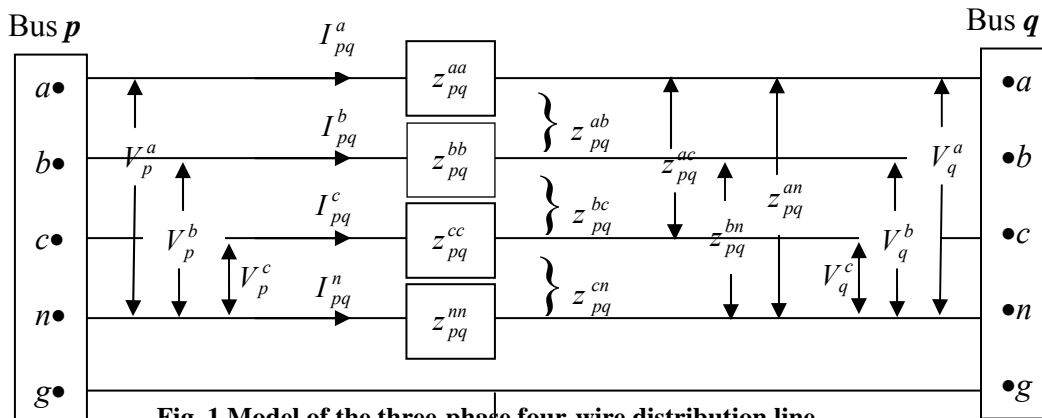


Fig. 1 Model of the three-phase four-wire distribution line

$$\begin{bmatrix} V_p^a \\ V_p^b \\ V_p^c \\ V_p^n \end{bmatrix} = \begin{bmatrix} V_q^a \\ V_q^b \\ V_q^c \\ V_q^n \end{bmatrix} + \begin{bmatrix} z_{pq}^{aa} & z_{pq}^{ab} & z_{pq}^{ac} & z_{pq}^{an} \\ z_{pq}^{ba} & z_{pq}^{bb} & z_{pq}^{bc} & z_{pq}^{bn} \\ z_{pq}^{ca} & z_{pq}^{cb} & z_{pq}^{cc} & z_{pq}^{cn} \\ z_{pq}^{na} & z_{pq}^{nb} & z_{pq}^{nc} & z_{pq}^{nn} \end{bmatrix} \begin{bmatrix} I_{pq}^a \\ I_{pq}^b \\ I_{pq}^c \\ I_{pq}^n \end{bmatrix} \tag{1}$$

Also representable in matrix form as

$$\begin{bmatrix} \mathbf{V}_p^{abc} \\ V_p^n \end{bmatrix} = \begin{bmatrix} \mathbf{V}_q^{abc} \\ V_q^n \end{bmatrix} + \begin{bmatrix} \mathbf{Z}_{pq}^{abc} & \mathbf{z}_{pq}^n \\ \mathbf{z}_{pq}^{nT} & z_{pq}^{nn} \end{bmatrix} \begin{bmatrix} \mathbf{I}_{pq}^{abc} \\ I_{pq}^n \end{bmatrix} \tag{2}$$

If the neutral is grounded, the voltage V_p^n and V_q^n can be considered to be equal. In case, from the 1st row of eqn. 2, it is possible to obtain

$$I_{pq}^n = -z_{pq}^{nn^{-1}} z_{pq}^n{}^T I_{pq}^{abc} \tag{3}$$

and substituting eqn. 3 into eqn. 2, the final form corresponding to the Kron's reduction becomes

$$V_p^{abc} = V_q^{abc} + Z e_{pq}^{abc} I_{pq}^{abc} \tag{4}$$

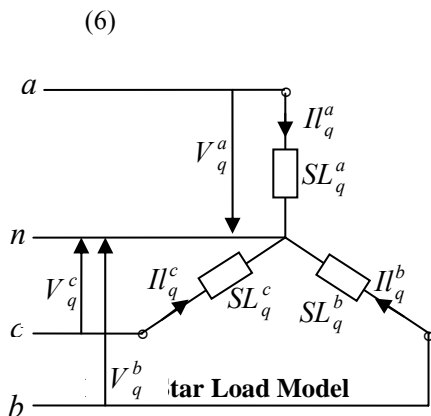
Where

$$Z e_{pq}^{abc} = Z_{pq}^{abc} - z_{pq}^n z_{pq}^{nn^{-1}} z_{pq}^n{}^T = \begin{bmatrix} z e_{pq}^{aa} & z e_{pq}^{ab} & z e_{pq}^{ac} \\ z e_{pq}^{ba} & z e_{pq}^{bb} & z e_{pq}^{bc} \\ z e_{pq}^{ca} & z e_{pq}^{cb} & z e_{pq}^{cc} \end{bmatrix} \tag{5}$$

I_{pq}^{abc} is the Current vector through line between bus p and q , can be equal to, the sum of the load currents of all the buses beyond line between bus p and q plus the sum of the charging currents of all the buses beyond line between bus p and q , of each phase.

There fore the bus q voltage can be computed when we know the bus p voltage, mathematically, by rewriting eqn. (4)

$$\begin{bmatrix} V_q^a \\ V_q^b \\ V_q^c \end{bmatrix} = \begin{bmatrix} V_p^a \\ V_p^b \\ V_p^c \end{bmatrix} - \begin{bmatrix} z e_{pq}^{aa} & z e_{pq}^{ab} & z e_{pq}^{ac} \\ z e_{pq}^{ba} & z e_{pq}^{bb} & z e_{pq}^{bc} \\ z e_{pq}^{ca} & z e_{pq}^{cb} & z e_{pq}^{cc} \end{bmatrix} \begin{bmatrix} I_{pq}^a \\ I_{pq}^b \\ I_{pq}^c \end{bmatrix} \tag{6}$$



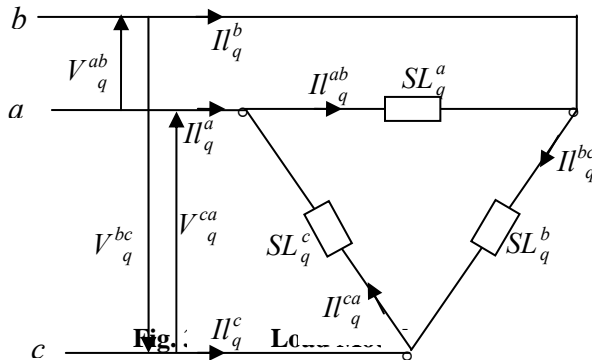
The Fig. 2 and 3 show the three phase unbalanced spot load model. In Fig. 2 and 3 show the star and delta three-phase loads may not be balanced. That is considering bus q , SL_q^a , SL_q^b and SL_q^c can be of different values or even zeroes. In fact, double-phase and single-phase

MODELING OF LOADS

The loads are generally available in the three phase unbalanced distribution systems as spot and distributed loads.

SPOT LOADS

All the loads are assumed to draw complex power ($SL_q = PL_q + jQL_q$). It is further assumed that all three-phase loads are star and delta connected and all double- and single-phase loads are connected between line and neutral and line to line respectively.



loads are modeled by setting the values of the complex power of the non-existing phases to zero.

In the case of three phase loads connected in star or single phase loads connected line to neutral, the load current injections at the q th bus can be given by:



$$\begin{bmatrix} I_q^a \\ I_q^b \\ I_q^c \end{bmatrix} = \begin{bmatrix} \left(\frac{SL_q^a}{V_q^a} \right)^* * |V_q^a|^n \\ \left(\frac{SL_q^b}{V_q^b} \right)^* * |V_q^b|^n \\ \left(\frac{SL_q^c}{V_q^c} \right)^* * |V_q^c|^n \end{bmatrix} = \begin{bmatrix} \left(\frac{PL_q^a + jQL_q^a}{V_q^a} \right)^* * |V_q^a|^n \\ \left(\frac{PL_q^b + jQL_q^b}{V_q^b} \right)^* * |V_q^b|^n \\ \left(\frac{PL_q^c + jQL_q^c}{V_q^c} \right)^* * |V_q^c|^n \end{bmatrix} \quad (7)$$

The current injections at the q th bus for three phase loads connected in delta or single phase loads connected line to line can be expressed by:

$$\begin{bmatrix} I_q^a \\ I_q^b \\ I_q^c \end{bmatrix} = \begin{bmatrix} \left(\frac{SL_q^{ab}}{V_q^{ab}} \right)^* * |V_q^{ab}|^n - \left(\frac{SL_q^{ca}}{V_q^{ca}} \right)^* * |V_q^{ca}|^n \\ \left(\frac{SL_q^{bc}}{V_q^{bc}} \right)^* * |V_q^{bc}|^n - \left(\frac{SL_q^{ab}}{V_q^{ab}} \right)^* * |V_q^{ab}|^n \\ \left(\frac{SL_q^{ca}}{V_q^{ca}} \right)^* * |V_q^{ca}|^n - \left(\frac{SL_q^{bc}}{V_q^{bc}} \right)^* * |V_q^{bc}|^n \end{bmatrix} \quad (8)$$

$$= \begin{bmatrix} \left(\frac{PL_q^{ab} + jQL_q^{ab}}{V_q^{ab}} \right)^* * |V_q^{ab}|^n - \left(\frac{PL_q^{ca} + jQL_q^{ca}}{V_q^{ca}} \right)^* * |V_q^{ca}|^n \\ \left(\frac{PL_q^{bc} + jQL_q^{bc}}{V_q^{bc}} \right)^* * |V_q^{bc}|^n - \left(\frac{PL_q^{ab} + jQL_q^{ab}}{V_q^{ab}} \right)^* * |V_q^{ab}|^n \\ \left(\frac{PL_q^{ca} + jQL_q^{ca}}{V_q^{ca}} \right)^* * |V_q^{ca}|^n - \left(\frac{PL_q^{bc} + jQL_q^{bc}}{V_q^{bc}} \right)^* * |V_q^{bc}|^n \end{bmatrix}$$

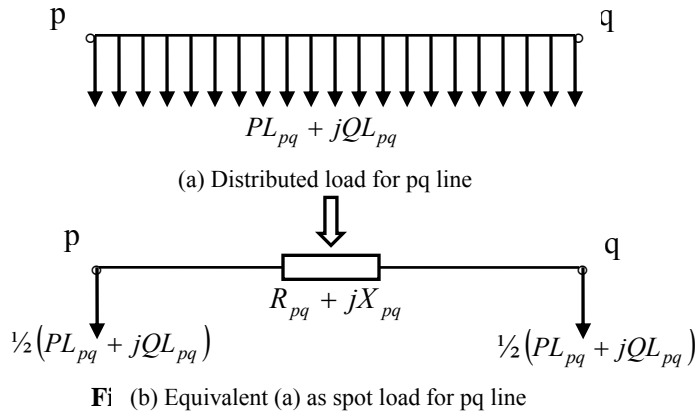
Eqn. (7) and (8) represents a generalized model for star and delta load models. Where the n is defined as follows:

- $n=0$ constant power
- $n=1$ constant current
- $n=2$ constant impedance

DISTRIBUTED LOADS

In the unbalanced distribution system, loads can be uniformly distributed long a line. When the loads are uniformly distributed, it is not necessary to model each and every load in order to determine the voltage drop from the source end to the last loads.

From D. Shirmohammadi [19], the total distributed load on each phase of a line section is lumped half-half at the line section's of two end buses. So now the load is at bus p and bus q can be model as spot loads shown in the Fig. 4. Depending on the spot load type use the eqns. (7) and (8) to calculate the load current at respective p and q buses.



Line Shunt Charging Model

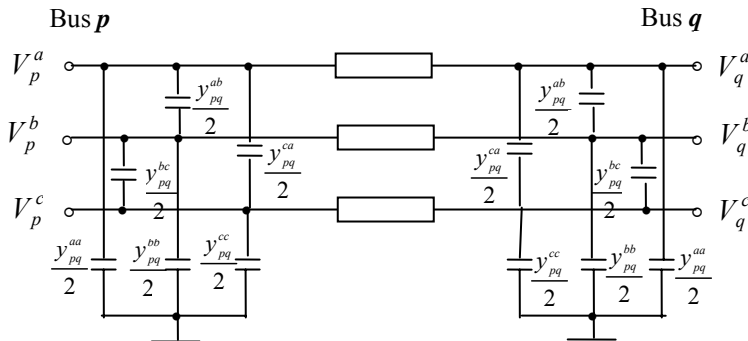


Fig-5 Shunt capacitance of line sections

The previous line section model can be improved by the inclusion of line charging representation. The shunt capacitances phase to phase and phase to ground, depicted in Fig. 5, can be taken into account through additional current injections.

These current injections for representing line charging, which should be added to the respective compensation current injections at buses *p* and *q*, are given by

$$\begin{bmatrix} Ish_q^a \\ Ish_q^b \\ Ish_q^c \end{bmatrix} = \frac{1}{2} \begin{bmatrix} -(y_{pq}^{aa} + y_{pq}^{ab} + y_{pq}^{ac}) & y_{pq}^{ab} & y_{pq}^{ac} \\ y_{pq}^{ba} & -(y_{pq}^{ba} + y_{pq}^{bb} + y_{pq}^{bc}) & y_{pq}^{bc} \\ y_{pq}^{ca} & y_{pq}^{cb} & -(y_{pq}^{ca} + y_{pq}^{cb} + y_{pq}^{cc}) \end{bmatrix} \begin{bmatrix} V_q^a \\ V_q^b \\ V_q^c \end{bmatrix} \tag{9}$$

LINE CURRENT CALCULATION

A bus in a radial system is connected to several other buses. However, owing to the structure, in a radial system, it is obvious that a bus is connected to the substation through only one line that feeds the bus. All the other lines

connecting the bus to other buses draw load current from the bus. Fig. 6 shows phase *a* of a three-phase system where lines between buses *p* and *q* feed the bus *q* and all the other lines connecting bus *q* draw current from line between bus *p* and *q*.

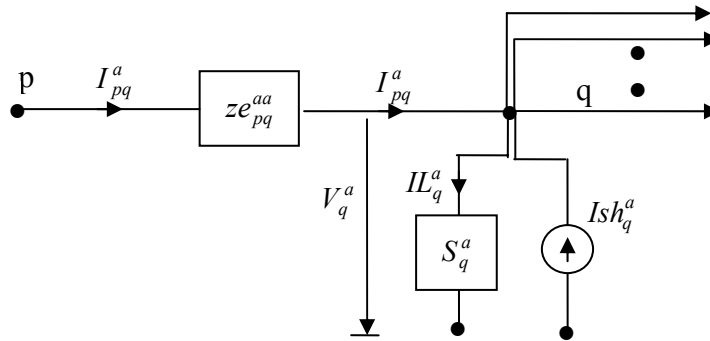


Fig. 6 Single phase line section with load connected at bus q between to phase a and neutral n .

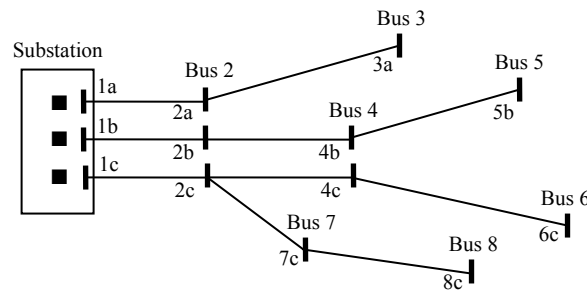


Fig. 7 An eight bus system

This is explained using an example. Consider the eight bus three-phase radial distribution system shown in Fig. 7. The total line current supplied through the phase a of the line between buses p and q at bus q side is equal to the following:

$$I_{12}^a = I_L_2^a + I_L_3^a + I_{sh}_2^a + I_{sh}_3^a \quad (10)$$

Thus, in general, the line current at any phase of line between buses p and q may be expressed as below:

$$I_{pq}^{abc} = \begin{bmatrix} I_{pq}^a \\ I_{pq}^b \\ I_{pq}^c \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{N(pq)} I_{IE(pq,i)}^a + \sum_{i=1}^{N(pq)} I_{sh_{IE(pq,i)}}^a \\ \sum_{i=1}^{N(pq)} I_{IE(pq,i)}^b + \sum_{i=1}^{N(pq)} I_{sh_{IE(pq,i)}}^b \\ \sum_{i=1}^{N(pq)} I_{IE(pq,i)}^c + \sum_{i=1}^{N(pq)} I_{sh_{IE(pq,i)}}^c \end{bmatrix}$$

(11)

POWER LOSS CALCULATION

Eqn. 11 provides a method to compute the currents through the three phase of the branch between buses p and q .

Power fed into the phase a of line between bus p and q at bus p is $V_p^a \cdot (I_{pq}^a)^*$

Power fed into the phase a of line between bus p and q at bus q is $V_q^a \cdot (I_{qp}^a)^*$

Therefore real and reactive power losses in the line between bus p and q may be written as:

$$\begin{bmatrix} LS_{pq}^a \\ LS_{pq}^b \\ LS_{pq}^c \end{bmatrix} = \begin{bmatrix} LP_{pq}^a + jLQ_{pq}^a \\ LP_{pq}^b + jLQ_{pq}^b \\ LP_{pq}^c + jLQ_{pq}^c \end{bmatrix} = \begin{bmatrix} V_p^a \cdot (I_{pq}^a)^* - V_q^a \cdot (I_{qp}^a)^* \\ V_p^b \cdot (I_{pq}^b)^* - V_q^b \cdot (I_{qp}^b)^* \\ V_p^c \cdot (I_{pq}^c)^* - V_q^c \cdot (I_{qp}^c)^* \end{bmatrix} \quad (12)$$

ALGORITHM

The complete algorithm is presented in the flow chart given in Fig. 8 and 9. Fig. 8 shows the algorithm to find the number of buses belong one particular branch. Fig. 9 shows the algorithm

for load flow solution. In every iteration, the following steps are followed. Each bus p in the system is considered. As explained in the Load Model section using Fig. 6, only one line connecting the bus q to the substation feeds the bus q . The total line current supplied through this line to bus q is determined using eqn. (9).

With the knowledge of current flowing between buses p and q from eqn. (9) at the q th

bus, using eqn. (4), the algorithm computes the voltage at receiving end bus q for the line between buses p and q . In this method, the algorithm computes the voltages at all the buses of the system starting from the substation to all the buses downstream. The algorithm stops if the changes in the computed bus voltage magnitudes are the same in two successive iterations or if $IT \geq ITMAX$.

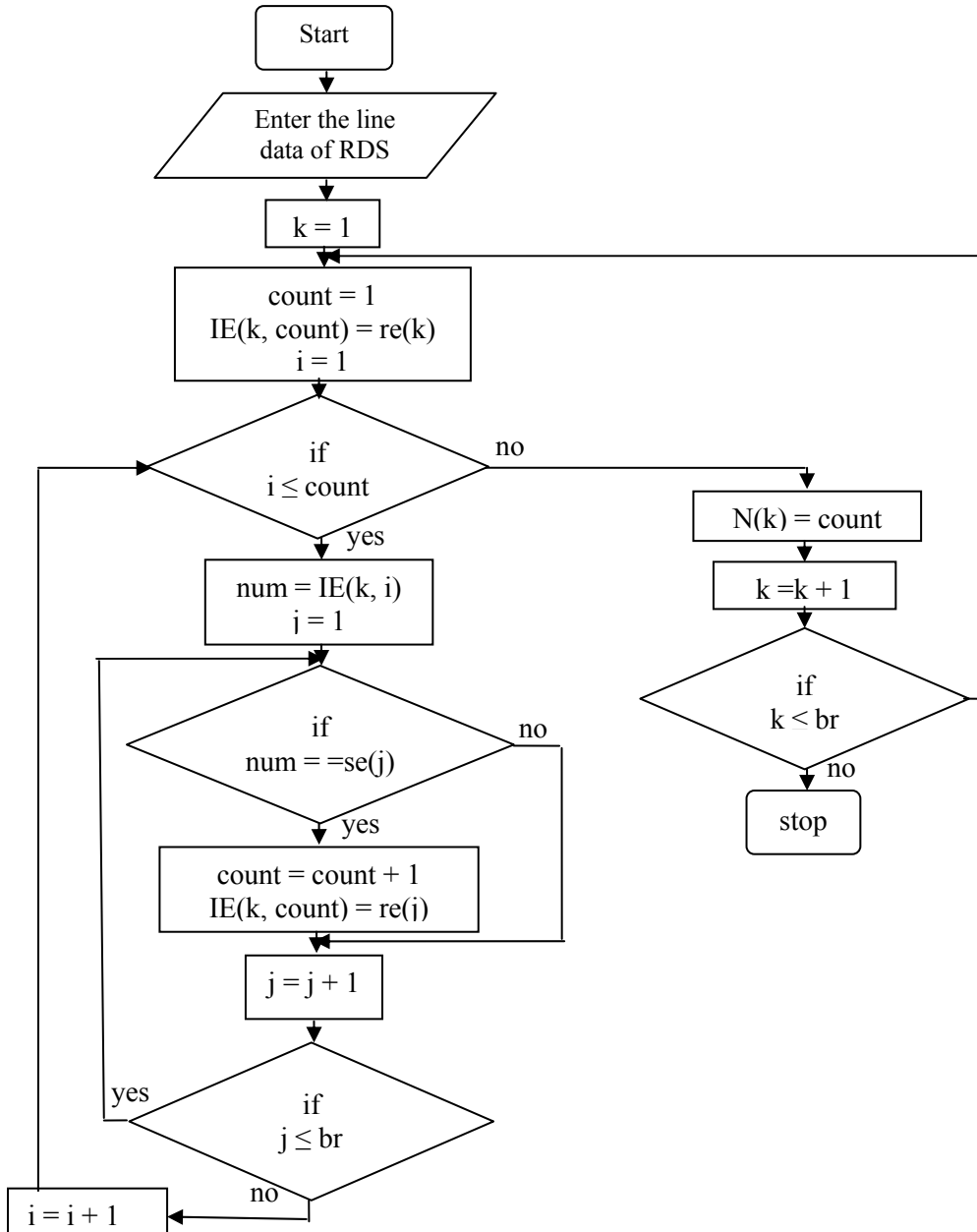


Fig. 8 Flow chart for identify the buses and branches beyond a particular bus

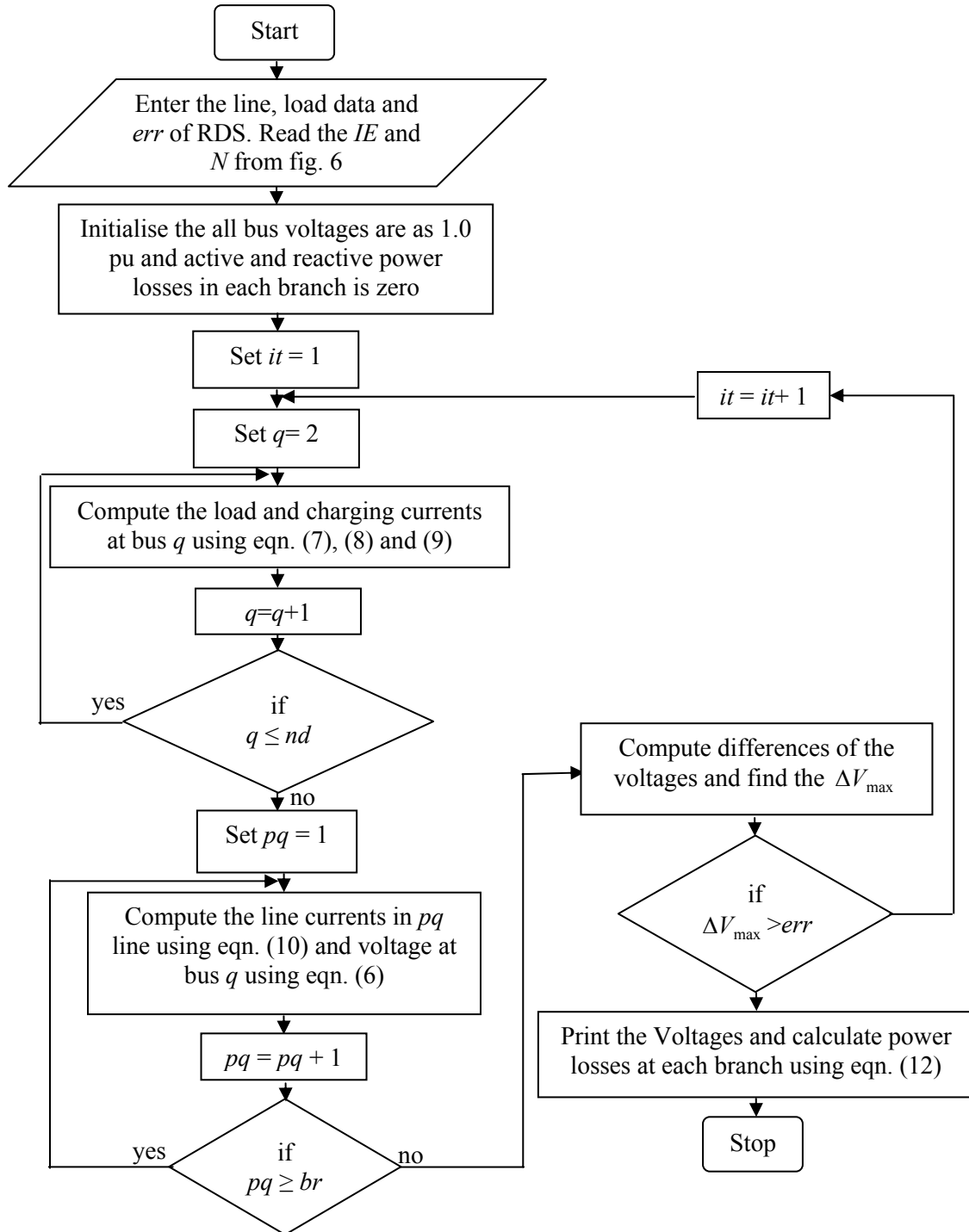


Fig. 9 Flow chart for Load Flow solution



ILLUSTRATED EXAMPLE STUDIES AND RESULTS

The effectiveness of the proposed method has been explained with two unbalanced radial distribution system.

Example 1

A sample system 14.4 kV of 8 buses shown in Fig. 7 has been taken from the Taiwan Power Corporation [14]. The base values of the system are 14.4 kV and 100 kVA. The convergence tolerance specified is 0.001 p.u. The converged solutions (voltage magnitudes and phase angles) are given in Table 1.

Table 1 Voltages and angle of the eight bus system

Bus No	Ladder Network Theory Method [17]		Proposed Method	
	V (p.u.)	Angle (deg.)	V (p.u.)	Angle (deg.)
1a	1.0000	0.00	1.0000	0.00
1b	1.0000	-120.00	1.0000	-120.00
1c	1.0000	120.00	1.0000	120.00
2a	0.9830	0.18	0.9830	0.18
2b	0.9714	-119.76	0.9714	-119.76
2c	0.9745	119.97	0.9745	119.97
3a	0.9822	0.18	0.9823	0.19
4b	0.9655	-119.73	0.9655	-119.73
4c	0.9716	119.93	0.9717	119.94
5b	0.9643	-119.74	0.9644	-119.74
6c	0.9697	119.92	0.9697	119.92
7c	0.9731	119.96	0.9731	119.96
8c	0.9719	119.95	0.9719	119.95

The results obtained by proposed method are compared with those given in [17] which are obtained using the Ladder Network Theory Method are shown in Table 1. For proposed method, the maximum deviation from the Ladder Network Theory Method is 0.0001 p.u and 0.01 deg.. Thus, the two discussed

methods are quite accurate. The minimum voltages are highlight in the Table 1

The number of iterations required for Ladder Network Theory Method and proposed method are found to be same. However, for a larger system, the number of iterations required for the Ladder Network Theory Method and proposed method may vary.

The execution time is 0.048 seconds for the Ladder Network Theory Method and 0.016 seconds for the proposed method on P-IV computer with 1.6 GHz frequency and 128 MB RAM.

For both methods the load flow converged in 2 iterations for the tolerance of 0.001 p.u. When the tolerance limit is set as 0.0001, the number of iterations required for the convergence is 3 for Ladder Network Theory Method and 2 for proposed method. The summary of results is shown in the Table 2.

Table 2 Summary of test result

Load Flow Method	Tolerance 0.001	Tolerance 0.0001
Ladder Network Theory Method [17]	2	3
Proposed Method	2	2

From the above discuss, in the point view of the number of iterations for the low tolerance and time of execution of the Proposed Method is superior compared with the Ladder Network Theory Method [17].

Example 2

In this paper, the standard 4.16 kV IEEE 13 Bus Radial Distribution System is used to evaluate the performance of the proposed load flow algorithm. The line data and load data of the system are given in [20]. It is assumed that the transformer at the substation is balanced, voltage regulators and capacitors at various buses is neglected. For the load flow, base voltage and base MVA are chosen as 4.16 kV and 100 MVA respectively. The results are presented in Table 3.

**Table 3 Test results of the IEEE 13 Bus RDS**

Bus	$ V_a $	$\angle V_a$	$ V_b $	$\angle V_b$	$ V_c $	$\angle V_c$
1	1.00000	0.000	1.00000	-120.000	1.00000	120.000
2	0.95376	-2.123	0.97153	-122.634	0.94217	117.457
3	0.92698	-5.237	0.97167	-122.765	0.87823	115.037
4	0.92698	-5.237	0.97167	-122.765	0.87823	115.037
5	0.95064	-2.198	0.96953	-122.683	0.93937	117.449
6	0.95064	-2.198	0.96953	-122.683	0.93937	117.449
7	-	-	0.95528	-123.266	0.94730	117.420
8	-	-	0.94965	-123.615	0.94944	117.432
9	0.92698	-5.237	0.97167	-122.765	0.87823	115.037
10	0.91870	-5.412	0.97289	-122.858	0.87424	115.154
11	0.92527	-5.289	-	-	0.87492	115.005
12	-	-	-	-	0.87163	114.925
13	0.92005	-5.215	-	-	-	-

The total system losses were found to be the following in each phase of the radial system:

- Phase A: 34.70 kW 150.49 kVAr
- Phase B: 18.67 kW 87.26 kVAr
- Phase C: 95.90 kW 197.25 kVAr

Application to find optimum location for reactive power compensation

The application of the proposed load flow solution method can also be demonstrated for reactive power compensation in distribution system. The candidate location for reactive power compensation can be defined as the location where the feeder losses are minimum when it is considered as the feeding source. Here the load flow is performed for one iteration at each node as possible feeding node and the losses are calculated. Then these losses are arranged in ascending order. The node, which is at the top of the merit order, is the optimum feeding node and it is the best location for reactive power compensation. Due to some geographical or other reason, if the first node in merit order is not suitable, the next node in the list is selected.

Application to network reconfiguration

The proposed load flow technique can be extended for network reconfiguration, as it is efficient and robust for analysing larger distribution system with higher number of nodes. First we can define the switching option with the available switches and total system losses can be calculated for each switching option. These loss values are arranged in merit order to obtain the optimum configuration.

CONCLUSIONS

In this paper, a simple and efficient computer algorithm has been presented to solve

unbalanced radial distribution networks. The proposed method has good convergence property for any practical distribution networks with practical R/X ratio. Computationally, this method is extremely efficient, as it solves simple algebraic recursive equations for voltage phasors. Another advantage of the proposed method is all the data is stored in vector form, thus saving enormous amount of computer memory. The proposed algorithm can be used effectively with Supervisory Control and Data Acquisition (SCADA) and Distribution Automation and Control (DAC) as the algorithm quickly gets the voltage solution and can be used to suggest rerouting or network reconfiguration for efficient operation of the system.

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