

# Analysis Distribution System for Power Loss and Voltage Profile Improvement using Load Flow Algorithm

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**ABSTRACT:** *Distribution companies are trying to reduce the high real loss and manage the poor voltage profile, so power loss minimization and voltage profile improvement are the main and important tasks to be faced by electrical engineers in the distribution system (DS). To achieve this goal requires knowledge for analyzing a radial distribution system (RDS) involves conducting power flow analysis, voltage regulation assessment, sensitivity analysis, and validation and verification processes to obtain reliable numerical results. Power flow analysis (PFA) determines the steady-state operating conditions by solving nonlinear equations representing power injection and consumption at each bus. The results include active and reactive power flows, indicating power demands and losses, as well as voltage magnitudes and phase angles, aiding in voltage stability assessment. (RDS) has been applied on operated example the standard IEEE 33-bus system and the results compared with the other popular algorithms. Overall, these analyses offer valuable insights for optimizing the power distribution system, identifying areas of concern, and improving system performance.*

**Keywords:** Distribution System (DS); Radial Distribution System (RDS); Power flow analysis (PFA).

## 1. INTRODUCTION

Distribution networks are one point in the energy distribution process where electricity is delivered to the end users. They are characterized as the portion

of an electrical system that provides the consumer with power from transformation points in the transmission system. The distribution network typically includes every component that extends from the distribution substation to the client meter. The power loss in distribution feeders caused by the Joule effect is one of these networks' primary issues. The losses, which may account for 13% of the entire power generation, are primarily attributable to demonstrable inductors. It makes sense that the operation of the power system prioritizes minimizing active power losses. Because active power losses raise marginal energy prices and produce operational network issues that increase their susceptibility to failure, limiting power losses helps energy merchants as well as network operators in addition to end users. The latter is crucial since it has the potential to cause system instability and lower the level of dependability and security of the service. The following are among the most often used methods for lowering losses in distribution networks: connecting and disconnecting capacitor banks [1-5], installing distributed generation [6-11], reconfiguring the network, and combining any of the aforementioned methods [12-15].

It has already been demonstrated that a number of researchers have put forth several solutions to address the issues with power loss and low voltage profiles in distribution networks. The best ways to lower active and reactive power losses and keep all nodes' voltage profiles within the permitted IEEE range are capacitor placement, network

reconfiguration, DG integration, and simultaneous network reconfiguration and switchable capacitor insertion [16-20]. Many efforts have been made to solve both optimal capacitor bank placement and optimal network reconfiguration techniques using various modern optimization algorithms with various multi-objective functions. Previous research has typically considered optimal capacitor placement and optimal network reconfiguration techniques separately [21-25].

Overall, although having a significant impact on the distribution system's performance, prior research has not done much to examine the effects of concurrent capacitor allocation and network reconfiguration on power factor. Consequently, the primary goals of this research project are to lower power losses, improve the voltage profile, and raise the system's power factor [25].

## 2. METHODOLOGY

### 2.1 Load Flow Analysis of Radial Distribution Network

A well-designed and efficient distribution network is essential to meeting the rising demand for household, business, and industrial loads. For efficient load transfer planning, the radial distribution network's load-flow study is crucial. The majority of LFA algorithms that have been published thus far have mostly used forward and reverse sweep mechanisms. Since identifying leaf (terminal) nodes is essential to running the LFA algorithm and estimating network branch currents during the reverse sweep, the work presented in this chapter primarily suggests a novel LFA method that makes use of the effective leaf node identification scheme suggested [26-28]

### 2.2 Mathematical Model of Load Flow

The high R/X ratio in RDNs hinders the convergence of traditional load flow algorithms. An analogous single-line diagram can be used to depict a balanced RDN network. Because they are so little, the line shunt capacitances at the distribution voltage level can be disregarded. Fig.1 displays the condensed mathematical model of a segment of an RDN [29].

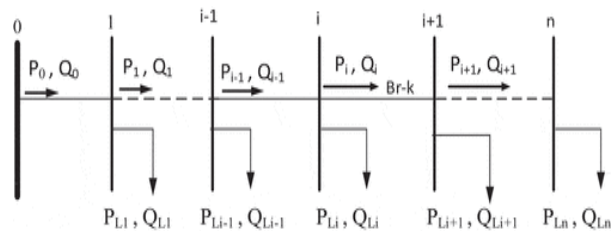


Figure 1. Simple distribution feeder

The complex power from feeder to node  $i$  will be represented by:

$$S_i = V_i(I_i)^* = P_i + jQ_i$$

$$\theta_i = \theta_{v_i} - \angle \tan^{-1}(-Q_{Li}/P_{Li})$$

Branch current calculation:

$$I_{br_i} = \sum_{i=1}^n |I_i| \cos \theta_i + j \sum_{i=1}^n |I_i| \sin \theta_i$$

$$\angle I_{br_i} = \tan^{-1} \frac{\text{Im}(I_{br_i})}{\text{Re}(I_{br_i})}$$

Voltage calculation: The following equation already illustrates how the voltage magnitude and angle at each node can be computed using the forward direction.

$$V_r = V_s - I_{br} \cdot Z_{br}$$

$$|V_r|^2 = |V_s|^2 + |I_{br}|^2 \cdot |Z_{br}|^2 - 2|V_s| \cdot |I_{br}| \cdot |Z_{br}| \cos(\theta_{V_s} - \theta)$$

$$\theta_{V_r} = \tan^{-1} \left[ \frac{|V_s| \sin \theta_{V_s} - |I_{br}| \cdot |Z_{br}| \sin \theta}{|V_s| \cos \theta_{V_s} - |I_{br}| \cdot |Z_{br}| \cos \theta} \right]$$

Therefore, the node voltages are approximated using the aforementioned equations once branch currents have been determined. Therefore, the calculation of branch currents is where the difficulty of the solutions lies. In order to determine the leaf node of an RDN and subsequently estimate the branch currents and node voltages, this study proposes a rather straightforward and. The following formula is used to calculate the real and reactive power losses in a given branch of the LFA algorithm

once the convergence criterion has been met during algorithm execution:

$$P_j = |I_{brj}|^2 \cdot R_{brj}$$

$$Q_j = |I_{brj}|^2 \cdot X_{brj}$$

It is possible to formulate the distribution line's real and reactive power loss as in the above equation.

**Constraints:** The following limitations are applied to the objective function.

**Limitations on voltage:** After the capacitors are placed, the voltage magnitude at each bus must fall within a permitted range in order to provide a high-quality electrical supply. This can be represented as:  $V_{min} \leq V \leq V_{max}$

Where  $V_{min}$  and  $V_{max}$  are taken as 0.95 pu and 1.05 pu respectively.

### 2.3 Flowchart of the proposed load flow algorithm

The accompanying flow chart (Figure 2) provides a quick overview of the suggested load flow methodology. As seen, the iteration starts once the distribution system data, such as line resistance, reactance, and active and reactive power, are read. The computation of each branch line's effective real and reactive power flows using backward load flow sweep will come next.

The same methods used for power estimates are also used to determine the currents in this situation. Using forward load flow propagation, the voltage of each node starting from the substation will be computed once the currents and line flow active and reactive power have been established. If the voltages at each node converge to the predetermined limit, the system's active and reactive power losses will then be assessed. The standard IEEE 33-bus, which is frequently used as a test case in the analysis of the DSR problem, was taken here in

order to demonstrate the efficacy of the LFA on a medium voltage distribution system in Fig. 3.

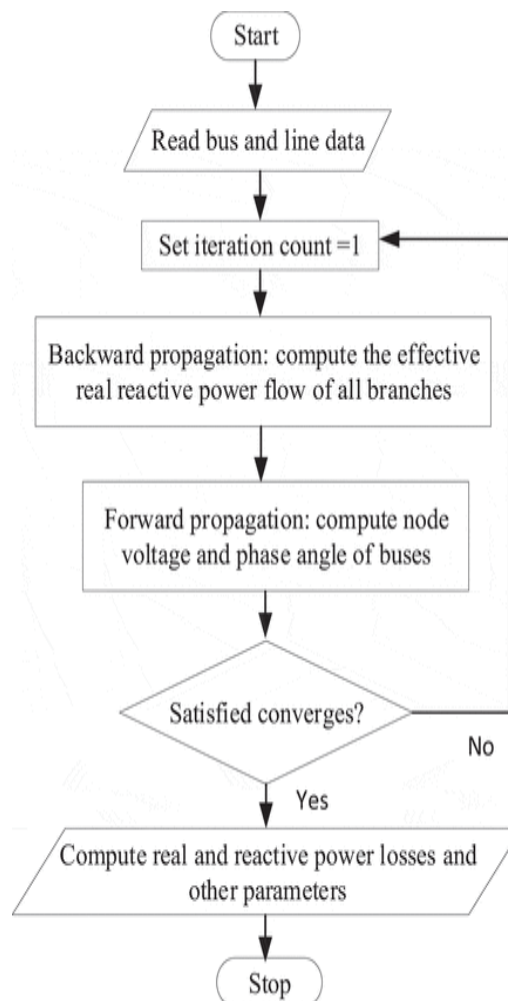


Figure 2. Flowchart of proposed method [30].

The objective of the study is to gain insights into the system's behavior and characteristics, particularly in terms of power flow and voltage regulation. The distribution system consists of 33 buses, with each bus representing a specific location or node. To analyze the system, a power flow analysis is conducted to determine power flow, voltage magnitudes, and phase angles at each bus. This analysis helps in understanding the power distribution within the system and identifying potential areas of congestion or voltage violations. Additionally, voltage regulation is assessed to ensure that voltage levels at each bus are within acceptable limits. The study examines voltage profiles to identify any voltage drop or rise issues that may

require corrective measures, such as tap adjustment or capacitor placement. [9]

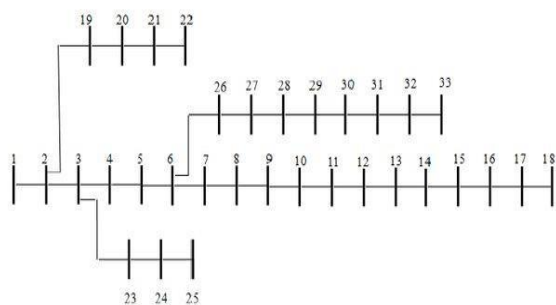


Figure 3. IEEE 33-Bus Radial Distribution System

### 3. NUMERICAL RESULTS

Analyzing a radial distribution system and obtaining numerical results requires comprehensive investigation and assessment of various parameters. By conducting a power flow analysis and voltage regulation assessment, valuable insights can be gained regarding power distribution, voltage stability, and overall system performance. The power flow analysis involves solving a set of nonlinear equations that describe the power injected and consumed at each bus in the distribution system.

By inputting load data-33 Bus and line data-33 Bus into a power flow analysis tool, numerical results can be obtained. These results include active and reactive power flows, providing information about power demands and losses within the network. Additionally, voltage magnitudes and phase angles are calculated, enabling the assessment of voltage stability and the identification of potential voltage violations. Analyzing these numerical results facilitates the understanding of power distribution patterns, identifies heavily loaded lines or buses, and helps optimize the system's performance. As shown in Figure 4, we can reach results after analyzing the voltage magnitudes for each specific node, to know the extent of the largest voltage drop at the distribution line and the extent of its effect, and to know the best node in which we find the highest voltage magnitude for all voltages, and we thus see that the highest voltage is 0.998 at Node 19, although the minimum effort is 0.882 at Node 18, and the arithmetic average value of the distribution lines after analyzing them appeared to be 0.93 p.u finally we seen that the amount of power loss equals 281.58 KW.

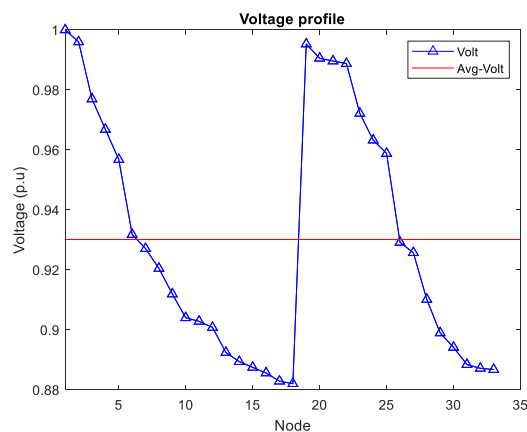


Figure 4. Voltage and Average Voltage profile for the 33-bus system. [10]

### 4. CONCLUSION

Analyzing the active power loss in DS is the main objective of this research paper. To estimate the impact of the proposed power loss, it is applied to the IEEE 33-bus standard. From the result of the test analysis, it was noted that the amount of power loss equals 281.58 KW and that the result of the arithmetic average of the voltage equals 0.93 p.u. Thus, the analysis was done properly. the analysis of a radial distribution system through power flow analysis, voltage regulation assessment, sensitivity analysis, and validation and verification processes provide valuable insights for optimizing system performance, identifying areas of concern, and making informed decisions regarding the operation and maintenance of the distribution network. In the near future, we aim to achieve the best way to reduce the amount of energy loss during distribution.

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## APPENDIX

TABLE I. Load & Line data of the IEEE 33-bus radial distribution system.[11]

| S. No | From bus | To bus | R      | X      | P KW | Q KVAR |
|-------|----------|--------|--------|--------|------|--------|
| 1     | 1        | 2      | 0.0922 | 0.047  | 100  | 60     |
| 2     | 2        | 3      | 0.493  | 0.2511 | 90   | 40     |
| 3     | 3        | 4      | 0.366  | 0.1864 | 120  | 80     |
| 4     | 4        | 5      | 0.3811 | 0.1941 | 60   | 30     |
| 4     | 5        | 6      | 0.819  | 0.707  | 60   | 20     |
| 6     | 6        | 7      | 0.1872 | 0.6188 | 200  | 100    |
| 7     | 7        | 8      | 0.7114 | 0.2351 | 200  | 100    |
| 8     | 8        | 9      | 1.03   | 0.74   | 60   | 20     |
| 9     | 9        | 10     | 1.044  | 0.74   | 60   | 20     |
| 10    | 10       | 11     | 0.1966 | 0.065  | 45   | 30     |
| 11    | 11       | 12     | 0.3744 | 0.1238 | 60   | 35     |
| 12    | 12       | 13     | 1.468  | 1.155  | 60   | 35     |
| 13    | 13       | 14     | 0.5416 | 0.7129 | 120  | 80     |
| 14    | 14       | 15     | 0.591  | 0.526  | 60   | 10     |
| 15    | 15       | 16     | 0.7463 | 0.545  | 60   | 20     |
| 16    | 16       | 17     | 1.289  | 1.721  | 60   | 20     |
| 17    | 17       | 18     | 0.732  | 0.574  | 90   | 40     |
| 18    | 2        | 19     | 0.164  | 0.1565 | 90   | 40     |
| 19    | 19       | 20     | 1.5042 | 1.3554 | 90   | 40     |
| 20    | 20       | 21     | 0.4095 | 0.4784 | 90   | 40     |
| 21    | 21       | 22     | 0.7089 | 0.9373 | 90   | 40     |
| 22    | 3        | 23     | 0.4512 | 0.3083 | 90   | 50     |
| 23    | 23       | 24     | 0.898  | 0.7091 | 420  | 200    |
| 24    | 24       | 25     | 0.896  | 0.7011 | 420  | 200    |
| 25    | 6        | 26     | 0.203  | 0.1034 | 60   | 25     |
| 26    | 26       | 27     | 0.2842 | 0.1447 | 60   | 25     |
| 27    | 27       | 28     | 1.059  | 0.9337 | 60   | 20     |
| 28    | 28       | 29     | 0.8042 | 0.7006 | 120  | 70     |
| 29    | 29       | 30     | 0.5075 | 0.2585 | 200  | 600    |
| 30    | 30       | 31     | 0.9744 | 0.963  | 150  | 70     |
| 31    | 31       | 32     | 0.3105 | 0.3619 | 210  | 100    |
| 32    | 32       | 33     | 0.341  | 0.5302 | 60   | 40     |