Section A-Research paper
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RECENT TRENDS OF LOAD FLOW TECHNIQUES IN DISTRIBUTION SYSTEM:- A REVIEW

Pinkey Singh[1] , Surender Singh[2] , Meena Kumari[3] , Manisha[4]
Assistant Professor, UIET MDU Rohtak[1,2,3,4]
E-mail:- pinkey.rp.uiet@mdurohtak.ac.in[1], surender.uiet@mdurohtak.ac.in[2]
meena.uiet@mdurohtak.ac.in[3], manisha.rp.uiet@mdurohtak.ac.in[4]

Abstract:

Load flow algorithms for power distribution systems (PDS) differ from those for transmission systems due to unique topological characteristics. The integration of renewable energy sources with electrical power systems has gained significant interest in recent years, offering environmental and financial benefits. However, this integration introduces additional uncertainties, requiring suitable uncertainty models for power systems. This paper covers both deterministic load flow (DLF) and probabilistic load flow (PLF) techniques. The IEEE-33 Bus system is utilized to assess uncertainty in line and load data. The results indicate favorable outcomes in terms of improving voltage profiles and reducing actual power losses.

Key Words: Probabilistic Load Flow (PLF), deterministic Load Flow (DLF), Newton-Raphson Method, Forward Backward Sweeping (FBS), Power Distribution Systems(PDS).

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1. Introduction:

Around the world, the size and complexity of the power system are constantly increasing. Today, more than ever, there is a great need for numerous system studies. Distribution networks are distinguished by their radial topology and high R/X ratio. When it comes to solving such networks, traditional power flow algorithms have a convergence problem [2-44]. Over the past few decades, numerous techniques for addressing power flow and uncertainty issues have been reported in the literature [45-64]. Despite this, researchers are currently working to develop faster, more reliable algorithms that nevertheless provide satisfactory results. To obtain information more quickly and precisely, the effects of voltage fluctuations are primarily taken into consideration. In terms of storage requirements and solution speed, these approaches are wasteful even for the converged cases. This led to the development of new load flow analysis methods incorporating distributed generation and different compensating devices [65-102].

This study traces the history of today's three-phase distribution load flow, which includes various feeding sources, embedded FACTS devices, Forward Backward Sweep (FBS)/Ladder Network-based approaches, Newton-like methods, and other fast decoupling methods, and Implicit Z-bus Gauss methods.

2. Load Flow Technique

The Ward and Hale approach introduced the load flow calculation studies in 1956 [1], and they have since grown to be a crucial and important tool in the field of power system engineering. They are used both during the planning and operational phases. The load flow problem must be solvable for systems with tens of thousands of nodes, several voltage levels, radial or mesh topologies, unbalanced loads, and distributed energy sources of any kind.

In this section, the approaches taken to address the load flow difficulty in distribution systems are described, taking into account their special traits and the numerous challenges that their prospective future advancements may provide. The load flow techniques have been categorized into two types, one for probabilistic load flow solution methods and the other for deterministic load flow solution methods as shown in figure 1.

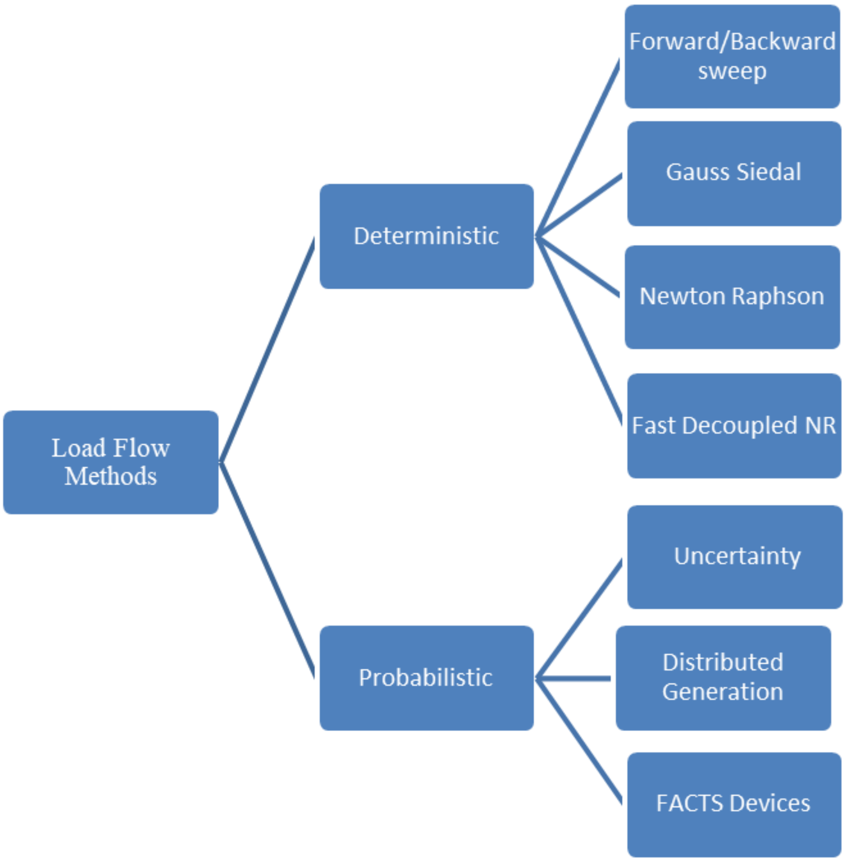

Figure 1. Classification of Load Flow Methods

2.1 Deterministic Load Flow Methods

Although there have been numerous approaches to the load flow issue in distribution systems, the majority of them fall into one of three categories: (i) backward/forward sweep methods; (ii) Newton-type approaches; and (iii) Gauss-Seidel approaches.

2.1.1 Ladder Network/Forward Backward Sweep (FBS) Based Methods

The most widely used technique for calculating distribution load flow [2–19] is this one. This method's initial iteration was developed using a radial system model and only considering PQ nodes. Since it was first put out [2], several improvements have been made that allow it to solve systems with weakly meshed topologies [3, 4], voltage-dependent loads [5, 6], distributed generation [6], three-phase [7] or three-phase four-wire systems, including neutral grounding [8].In a backward sweep method, iterations begin with estimates of the terminating bus voltages. The various bus voltages are then determined using a reverse trace, as a consequence, a computed value for the source voltage is obtained [9]. For the square of the magnitude of the voltage, a forward trace is used to solve a quadratic equation after the power is added up using a reverse trace of the system [10]. A weakly meshed structure compensation approach starts with a network structure analysis to determine the connectivity sites. The meshed system structure is then transformed into a basic tree-type radial system by breaking these connecting points [11]. Rather than complicated currents, active and reactive power are used as variables in this improved compensation-based load flow method [12]. Voltage regulators, shunt capacitors, and automatic local tap controllers for unbalanced and distributed loads, all while maintaining the high execution speed required in automated distribution systems for real-time applications [13]. The compensation approach for poorly meshed distribution networks has been improved to take into account the impacts of load and shunt admittance [14]. Two methods based on the admittance and current summation method have been reported [15-16]. A branch current summation-based FBS load flow algorithm has been presented [17]. To speed up the convergence of compensation-based systems, for meshed distribution networks, a two-stage load flow technique has been designed [18]. A power summation-based FBS load flow algorithm has been discussed [19].

2.1.2 Implicit Z-bus Gauss Methods

A bi-factorized complex Y admittance matrix is used in the Gauss Implicit method, which is based on Equivalent Current Injection (ECI) [20]. A load flow approach works for meshed distribution networks by developing a simple loop equation and describing loads as complex impedances [21]. To enhance computational performance, a modified Gauss-Siedel approach was developed with the combination of the Gauss-Siedel and implicit Z-bus methods. This approach, which factors the Y-three matrix's submatrices rather than the entire Y-matrix, works well with radial, weakly meshed, and looping networks [22]. This topological technique produces the matrices Bus Injection to Branch Current (BIBC) and Branch Current to Bus Voltage (BCBV). The load flow solution can be obtained by simply multiplying these two matrices [23].

2.1.3 Newton Like Methods and Modified Fast-Decoupled Methods

The load flow problem for ill-conditioned systems may not be solved by conventional Newton-Raphson or Newton-like methods. This problem has been solved using several Newton-like strategies [24– 30]. A method for addressing radial load flow as a subroutine within the optimum capacitor size issue, three nonlinear equations are developed for each branch. Some simplifications are applied to the Jacobian matrix to improve computing performance [24]. The typical three-phase decoupled theory is modified to produce a fast decoupled 3-phase load flow suitable for DSLF. The angle and voltage corrections are calculated and evaluated using the submatrices (B' and B") in this model [25]. The branch current-based NR approach is used in a phase-decoupled load flow method based on the ECI method. The approach is unaffected by line arguments and is much faster [26]. To depict the Jacobian matrix as a product of UDU Transpose, the network radial structure is evaluated using the modified NR approach, where U is the upper triangular matrix that is constant and D is a diagonal matrix whose components are entirely impacted by the system topology whose members are updated at each iteration [27]. The Jacobian matrix is presented in complicated form in this three-phase power flow formulation, Although, by removing the mismatch component induced by voltage variations, certain simplifications are introduced [28]. Current injection method, which is based on nodal current injections written in rectangular coordinates and takes voltage-dependent loads into account, is another Newton-like approach that is receiving considerable interest. [29]. The convergence of the backward/forward sweep method and the current injection approach have been thoroughly compared. [30].

Table 1
A brief review of deterministic load flow methods

Sr.No.	Reference No.	Technique/Method	Test System	findings
1	31(2012)	Fuzzy arithmetic and fuzzy logic principle	29−node	Improved voltage

2	32(2014)	F/B Sweep	IEEE 33 bus	Enhancing the voltage profile and minimizing losses
3	33(2016)	Compares the performance characteristics of Both the Forward/Backwards Sweep (FBS) method and the Newton-Raphson (NR) method	Test feeder for IEEE 13 nodes	Improving the voltage profile and reducing the real power losses
4	34(2017)	Backward and Forward Sweep	33 Node RDS and 69 Node RDS	Enhancing the voltage profile and minimizing losses
5	35(2018)	Backward and Forward Sweep	IEEE 69 bus	Real power losses reduce and node voltages improved
6	36(2019)	Modified backward/forward sweep algorithm	IEEE 13-node test feeder and the 123-node test feeder	Power loss reduces
7	37(2020)	Backward and Forward Sweep	A 15-bus system, IEEE 69-bus	Improved voltage
8	38(2021)	Backward and Forward Sweep	Systems for the IEEE 15 bus, IEEE 33 bus, and IEEE 69 bus	Improved voltage
9	39(2009)	the implicit Z-Bus Gauss method	The IEEE 4 Node Test Feeder	Reactive power losses reduce and node voltages improved
10	40(2020)	implicit Z-bus Gauss microgrid	The mesh microgrid	Improved voltage

		algorithm	with 33 buses	
11	41(2000)	Fast-decoupled *G*-matrix method	UNIX workstation	Less memory, faster
12	42(2000)	Newton–Raphson (NR) algorithm	Eight-bus distribution system with unbalanced loading	Robust and fast
13	43(2003)	Fast Decoupled Power Flow Method	IEEE 34-node system	The method is accurate, fast, stable
14	44(2021)	Newton-Raphson method	57-bus IEEE distribution test system	Actual power losses, reactive power losses, and voltage profile

The aforementioned findings demonstrate that, although the Gauss-Siedel approach is straightforward to apply, it becomes more time-consuming (requires more iterations) when the number of buses rises; Compared to other methods, the Newton-Raphson method is more accurate and yields better results with fewer iterations; Though the fastest technique, the fast decoupled method makes assumptions to speed up the calculation, hence it is less precise.

2.2 Probabilistic Load Flow-

The deterministic load flow problem excludes elements that can be extremely important when analyzing distribution networks with or without dispersed generation penetration, such as fluctuating load requirements and power oscillations brought on by renewable energy. To take the uncertainties into account, a different mathematical approach is required. The main sources of uncertainty in contemporary power systems include network failures, incorrect predictions, and random fluctuations in input data. Additionally, the rise of intermittent REs makes the uncertainty worse. One of the most promising tools, probabilistic power flow (PPF), is highly valued in a variety of power system applications. Borkowska first suggested using probabilistic analysis to examine electricity flow in 1974 [45]. It has also been used in other areas, such as short- and long-term planning, power system normal operation, and other domains [46]. PPF employs information about the uncertainties of the input variables to calculate the uncertainties of the output variables. A power system's output variables include bus voltage magnitudes and angles, branch power flows and losses, slack bus powers, and the generator buses' reactive power [47]. The hierarchy of uncertainty in the distribution system is shown in Figure 2.

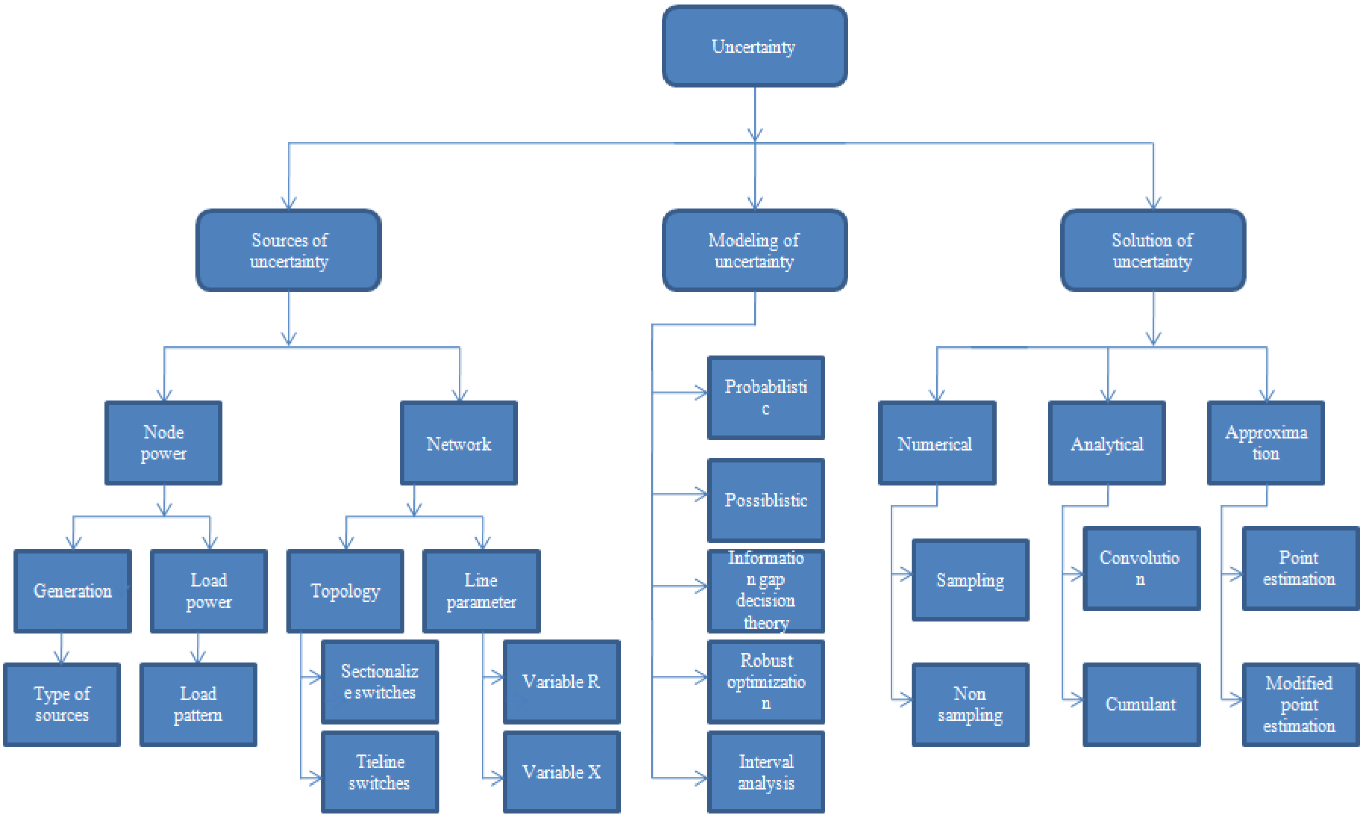

Figure 2. Schematic Diagram for Hierarchy of Uncertainty in Distribution System

2.2.1 Uncertainties in the distribution system

All feasible combinations of system inputs are examined to analyze the uncertainty in system planning. On the other hand, forecasting mistakes are used to reflect the system operating uncertainty. A radial distribution system using a fuzzy model in which load uncertainties are represented by fuzzy numbers [48]. An interval arithmetic technique that accounts for the input load parameters uncertainty and gives the problem strict boundaries [49]. For determining node voltages, branch current, and overall real and reactive power losses, interval arithmetic and fuzzy set theory are used [50]. To account for the unpredictable input parameters, the power flow method uses interval arithmetic [51]. A fuzzy distribution power flow method is used for load prediction uncertainty, system parameters, and voltage-dependent load model parameters like line reactance, bus shunts, and line resistance all at the same time [52]. Due to measurement mistakes, the input data is unreliable. To handle the uncertainties, the interval load flow solution was obtained using the interval mathematics (IM) tool [53]. The main sources of uncertainty are node power and network uncertainty. The unpredictability connected to generating units and system load requirements is dealt with by node power uncertainty. However, network uncertainties primarily result from line parameter changes or any network component failure. Utilizing uncertainty handling techniques primarily aims to quantify the impact of input parameter uncertainty on output parameters. The system model and the availability of input data are used to categorize these strategies. There are different uncertainty handling techniques which are presented in Table 2 with their advantages, disadvantages, and applications.

Table 2

Comparison of various methods for addressing uncertainty in power systems

Sr no.	Uncertainty handling	Advantages	Disadvantages	Application

	Technique			
1	Probabilistic	Easy implementation, accurate for complex and non-linear problems, dependency modeling.	Requires a large amount of historical data, computationally expensive, approximate output.	Power system planning and operation, reliability evaluation, electric railway system, stability examination.
2	Possibilistic	Model the uncertainty even if the historical data is missing/imprecise, extract numerical values from the linguistic information	Complex to implement, cannot model dependency, time taking.	Planning of power distribution networks as efficiently as possible, voltage stability.
3	Information gap decision theory is	useful for navigating the serious uncertainties in the electricity system.	Complexity is high.	Systems for managing energy, and planning for expanding OPF transmission.
4	Robust optimization	Useful for solving optimization problems considering RVs with a lack of information.	Cannot consider the correlation between the uncertainty sets, and is not simple to apply to non-linear models.	Unit commitment, frequency stability, optimization problems.
5	Interval analysis	Obtain the bounds of the output using the bounds of the input.	The connection between the intervals cannot be modeled.	Reliability evaluation, power system operation.

Only when sufficient historical data regarding uncertain variables or associated PDFs are available can probabilistic approaches be used [54]. The probabilistic load flow problem can be resolved analytically and numerically. The fundamental strategies incorporated into the probabilistic load flow solution are summarised here, along with examples of how they are used in distribution system analysis-

1) Methods based on numerical data and sampling: These include Quasi-MCS (QMCS), Non-sampling, Uniform Design Sampling (UDS), and Monte Carlo Simulation (MCS).

2) Analytical techniques: These comprise the Cumulant Method (CM), the Convolution Technique, and others.

3) Methods based on approximation: It includes Point Estimation Method (PEM), the Modified point estimation method i.e. unscented transformation method (UTM), etc.

1. Numerical solution methods

A Monte Carlo simulation approach’s two main parts are random sampling and random number production. Essentially, load flow with uncertainty based on this method includes solving a deterministic power flow with inputs in different combinations repeatedly utilizing the nonlinear form of the load flow equations. [55]. Due to the application of exact load flow equations, findings from this approach are frequently compared to validate their accuracy and compare them to other probabilistic load flow systems.

2. Analytical solution methods

Analytical methods (Ams) are suggested to reduce the computational cost involved with simulation-based approaches. These techniques outperform simulation-based techniques in terms of computational efficiency. To conduct PPF, they need several assumptions [56–58]. Input independence, network setup as a fixed parameter, linearization of load flow equations, and probability distribution for the loads are some of the often utilized assumptions.

The main concept of the analytical technique is to conduct arithmetic using the density functions of random input variables to obtain the density functions of random state variables and line flows. Though it can be difficult to solve probabilistic load flow equations for a variety of reasons, there are two: Because input power variables may not be independent of one another and load flow equations are nonlinear, this is possible.

3. Approximate methods (APMs)

The Point estimation method (PEM) and the Unscented transformation method are the most commonly used APMs.Emilio Rosenblueth first presented the PEM in 1975 [59] to control symmetric RVs, and the method's application was extended to cover both correlated and unsymmetric RVs in 1981 [60]. The PEM variations and their performance comparison are presented in [61]. The unscented transformation method was proposed to use the linearization technique to address the drawbacks of probabilistic power flow (PPF) methods [62]. In evaluating the statistics of output RVs going through non-linear transformations, this technique has performed well. The fundamental principle of UTM is that approximating a probability density function (PDF) is more convenient than approximating any nonlinear function [63]. Even when the system size is big, UTM produces findings that are extremely precise and require less computing time [64].

2.2.2 Multiple Feeding Sources (Distributed Generation)

With PV node compensation, the compensation-based power flow mechanism has been expanded to a Dispersed Generation (DG) distribution system [65]. Co-generators and recent technological advancements in energy storage devices, microturbines, and fuel cells have enabled scattered generation at the distribution level in terrestrial distribution networks [66]. The iterative process of power flow computation is faster and more reliable when voltage correction is included. A 3-phase unbalanced system with DG is subjected to the compensation-based technique [67]. For distribution systems with DGs and loops, a general load flow approach is used. To employ the recursive equations, distribution systems with numerous feeding sources and mesh configurations must first be transformed into an equivalent single-source radial system [68]. A power flow approach based on adaptive compensation is described [69]. PV buses will be represented in a novel way in the Three-phase Current Injection Method (TCIM). As a new state variable, the reactive power is represented, this formulation necessitates an augmented linearized system of equations [70]. The voltage control devices and distributed generators automatically adjust the reactive power outputs of static VAR compensators, synchronous generators, switched capacitors, regulating transformer tap positions, and induction generators using a sensitivity-based approach [71]. The substation and participating DGs' real power outputs can be modified using participation factors, and a distributed slack bus model based on Newton Raphson power flow solver is utilized [72]. A power flow system of three-phase that takes into account transformer voltage regulation as well as distributed generation [73]. Using the voltage stability index as a guide, a technique for optimal distributed generation siting has been developed. The applicability of the Wind Turbine Generator System (WTGS) is highlighted [74].

Table 3

A brief review of distributed generation sources

Sr.No.	Reference No.	Technique/Algorithm	Test System	Findings	Remarks
1	75(2010)	Genetic Algorithms (GA)	33 bus	Reduces real power loss,	4 DG is the best choice for voltage improvement
2	76(2011)	Artificial bee colony (ABC)	33,69 bus	The best DG unit size, and placement to minimize the system's overall real power loss and power factor	reliable, effective, and able to handle mixed integer nonlinear optimization issues
3	77(2013)	Modified Bacterial Foraging Optimization (MBFO)	12-bus system, 34-bus system, and 69-bus system	Decreases overall power loss and enhances voltage profile	Proper sizing and placement of DG
4	78(2015)	Multi-objective index-based approach	16-bus and 12 bus	Decreases actual power loss and enhances voltage profile	Location, size of DG, and voltage index
5	79 (2016)	Particle Swarm Optimization (PSO) algorithm, Impedance based method for fault location	IEEE 12 bus	Power loss is reduced	Fault location is identified, optimal DG placement and size, Voltage Stability Index (VSI)
6	80(2017)	Hybrid grey wolf optimizer (HGWO)	Indian 85-bus system, IEEE 69-bus system, and IEEE 33-bus system	Minimize the power loss, enhancement of the voltage profile	
7	81(2019)	To identify potential buses for the insertion of APF in the presence of	33-bus RDS with nonlinear load	Active power filter (APF) placement and sizing were	The outputs of GWO are compared with those of

		nonlinear load, the new nonlinear load position-based APF current injection (NLPCI) technique is developed. The ideal size of the APF is found using the Grey Wolf Optimizer (GWO).		optimized, and the result was a nearly 2.5-fold decrease in APF ratings.	harmony search and particle swarm optimization (PSO) (HS), THD
8	82(2019)	Salp swarm algorithm (SSA)	IEEE 33 and 69 bus	Decreased power loss, voltage variations, and increased bus voltage stability	Optimal allocation of DGs and CBs, total electrical energy cost reduced
9	83(2019)	Multi-objective opposition-based chaotic differential evolution (MOCDE)	IEEE-33 and IEEE-69 bus system	Power loss and yearly economic loss minimization as well as improvement of voltage profile	Positioning of DGs in ideal places and of ideal sizes.
10	84(2018)	Branch wise minimization technique (BWMT)	16-node radial distribution network	Reduce the system's capital and energy loss costs as much as possible. power loss reduction	
11	85(2019)	A hybrid approach based on PSO	17-Node System	Reduced real loss and better voltage profile	Optimal location of the substation
12	86(2018)	Particle Swarm Optimization (PSO)		Power loss reduction	Optimal conductor and then the location of the optimal conductor
13	87(2018)	Particle Swarm Optimization (PSO)		Real power loss and	Substation location,

				voltage deviation index.	feeder numbers, their routes, best conductor choice, quantity and placement of connecting lines, and sectionalizing switches
14	88(2022)	Firefly Analytical Hierarchy Algorithm (FAHA)	118-bus system	Improve the overall voltage profile, to reduce power loss and raise the network stability index.	Voltage stability index (VSI).

2.2.3 Application of Flexible Alternating Current Transmission Systems (FACTS) Devices

In a radial distribution system, the Thyristor Controlled Series Capacitor (TCSC) is a comparable approach for improving voltage control [89]. In a modified Newton approach in rectangular dimensions, an extended Jacobian matrix is necessary to handle the extra series FACTS devices connection between each control action and control variable [90]. With ideally arranged D-STATCOM, a load flow approach that accommodates numerous sources and looping of distribution networks is used [91]. The embedded series is incorporated into a Line Flow Based (LFB) formulation of power balance equations for analyzing a radial distribution system and shunt FACTS devices efficiently [92].

Table 4
A brief review of FACTS Devices

Sr.No.	Reference No.	Technique/Device	Test System	Findings	Remarks
1	93(2010)	Algorithm Line Flow Based Decoupled with embedded series FACTS device (TCSC) is implemented	IEEE 34-bus system	Improved voltage profile	
2	94(2012)	Discrete Particle Swarm Optimization(DPSO)	15-node RDS, 33-node	Achieving optimal voltage control,	Power Loss Index (PLI)

				decreasing the total cost and power losses,	
3	95(2013)	D-STATCOM	IEEE 33-bus RDS	Improved voltage profile, reduction in power loss	Ideal placement and size of DSATATCOM
4	96(2014)	Unified Power Flow Controller(UPFC)	IEEE 33-bus RDS	Reduce both active and reactive losses while keeping the voltage within acceptable limits.	
5	97(2015)	Bacterial Foraging Optimization Algorithm (BFOA)	IEEE 33-bus system and 119-bus system	Reducing power loss, operating expenses, and improving voltage profiles	The optimal size of DG and DSTATCOM, Loss sensitivity factor
6	98(2016)	Forward-Backward sweep load flow algorithm/ DSTATCOM	IEEE-33 bus RDS	Reduction in power loss	Minimizing annual energy loss costs (AELC) and increasing total economic savings costs (TESC)
7	99(2017)	The back-tracking Search Algorithm (BSA)	IEEE 33 Bus RDS	Reduction in power loss	Thyristor-controlled series compensator (TCSC), capacitor banks, and distributed generations (DGs) optimal sizing and placement
8	100(2018)	Combining General Algebraic Modeling System with Particle	33-bus, 69-bus, and 30-bus	Improvements in power losses, voltage	Optimal placement and sizing of

		Swarm Optimization	real-time distribution system	profiles, and voltage stability margins, as well as cost-savings on energy loss and yearly energy savings	D-STATCOM
9	101(2019)	Forward-backward sweep method /gravitational search algorithm (GSA)	IEEE 33 and IEEE 69 bus systems	Total power loss minimization, reduction of the voltage profile index, increase in voltage profile, and increase in total yearly energy savings	Appropriate position and capacity of D-STATCOM
10	102(2020)	Weighted Multi-objective optimization technique	IEEE 5 bus system	Real and Reactive power flow, Bus voltage, Real and reactive power loses	Sensitive bus identified

3. Mathematical Model:

3.1 Radial Distribution Systems

The three-phase radial distribution network is considered to be balanced and can be depicted by an equivalent single-line diagram as shown in Figure 2.

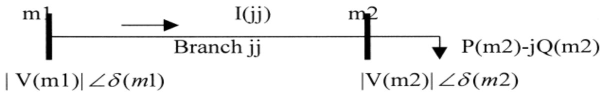

Figure 3. Diagram of a balanced power system in a single line

The load current is computed as follows:

$$I_{jj} = \frac{|V_{m1}| \angle \delta_{m1} - |V_{m2}| \angle \delta_{m2}}{Z_{jj}} \quad (1)$$

$$P_{m2} - jQ_{m2} = V_{m2} * I_{jj} \quad (2)$$

$$P_{loss} = \frac{R_{jj} * \left(P_{m2}^{2} + Q_{m2}^{2} \right)}{\left| V_{m2}^{2} \right|} \quad (3)$$

$$Q_{loss} = \frac{X_{jj} * \left(P_{m2}^{2} + Q_{m2}^{2}\right)}{\left|V_{m2}^{2}\right|} \qquad (4)$$

Where
V(m1) sending end node voltage
V(m2) receiving end node voltage,
P_{loss} and Q_{loss} are real and reactive power losses of the branch (JJ).

3.2 Load Variations

Uncertainties due to errors in load forecast, errors in the measured value of the transformer, and fluctuation in load demand in bound form may be expressed as:

$$P_i = P_0(1 \pm \lambda) \qquad (5)$$

$$Q_i = Q_0(1 \pm \lambda) \qquad (6)$$

Where λ represent the variation in real and reactive power.

4. Proposed Algorithm:

That actual line data is necessary for computing the load flow solution and, consequently, line losses and load data of the test system. In the RDS domain, the major algorithms for load flow analysis consider load as a continuous power load. However, as discussed above, the load data is the function of consumer demand. So, in this paper, we have considered three different cases of load demand. Therefore, it is necessary to modify traditional load flow analysis methods as per the load data specified in the input data. The detailed algorithm and Pseudo code for this load flow analysis is given below-

4.1 Load flow Algorithm:

i. Read the system input data including line data, and loads at various buses.
ii. Determine the nodes beyond each branch and the total number of nodes
iii. Voltages at all the buses including the source node are initialized to a flat start of 1.0 p.u.
iv. Solve the conventional load flow equations (1) - (4) and find out the current, node voltage, and system real and reactive losses.
v. Load data (P & Q) are updated by solving equations (5 & 6).
vi. Then solve the load flow equations (1-4) and find the current, node voltage, and system real and reactive losses.
vii. At last, find the results of load flow for the three different cases and print the results.

5. Result Analysis:

The suggested method was evaluated against previously described RDS networks in research papers to ensure its effectiveness and accuracy. However, for the sake of this presentation, 33 Node RDS was taken into account. The published paper [103] contains data from 33 nodes with a 12.66 kV RDS. In the base situation, total reactive power losses were 143.1518 kVAr, and total actual power losses were 211.1553 kW. The lowest voltage measured was 0.9062p.u.The suggested technique was tested with varying load data, and the results are shown in Table 1.

Table 5

Base case with IEEE 33 node RDS load flow findings with Load data variation

	Base Case	Case 1	Case 2
		1+δ	1-δ
Total Real Power Loss (kW)	211.1553	234.7912	188.9759

Total Reactive Power Loss (kVAr)	143.1518	159.2023	128.0941
Minimum Voltage (p.u)	0.9062	0.9012	0.9112
Maximum Voltage (p.u)	0.997	0.9969	0.9972

where,

Case 1: where Load data increased in a step of 5%

Case 2: where Load data decreased in a step of 5%

In this case study, the changes in load data are represented by δ and are taken as 5%.

Figure 4 depicts the influence of Case 1 and Case 2 on the current profile in contrast to the Base Case for 33 node RDS.

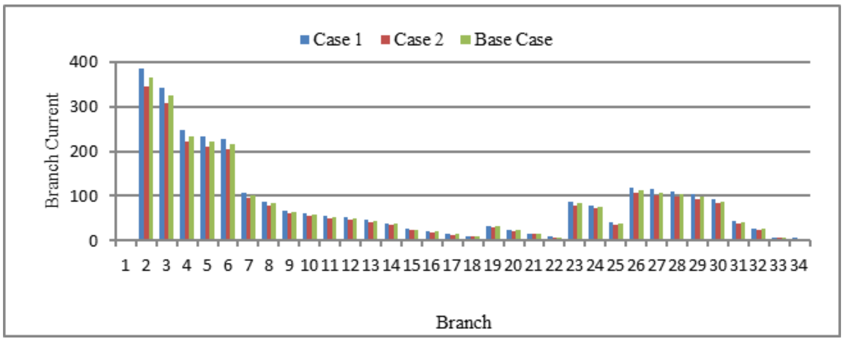

Figure 4. Current Profile of 33 Node RDS

Figure 5 depicts the influence of Case 1 and Case 2 on the voltage profile in contrast to the Base Case for 33 node RDS.

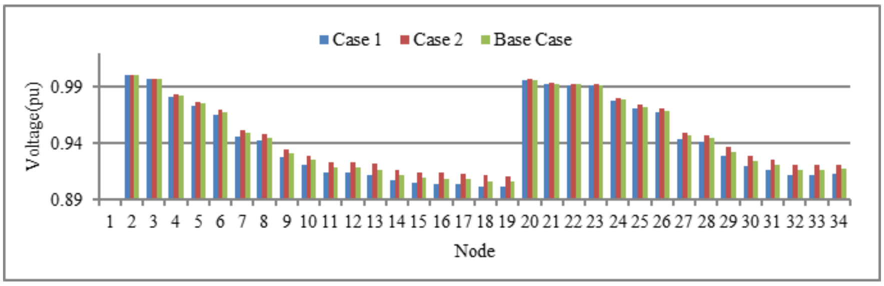

Figure 5. VoltageProfile of 33 Node RDS

Figure 6 depicts the influence of Case 1 and Case 2 on the real power loss profile in contrast to the Base Case for 33 node RDS.

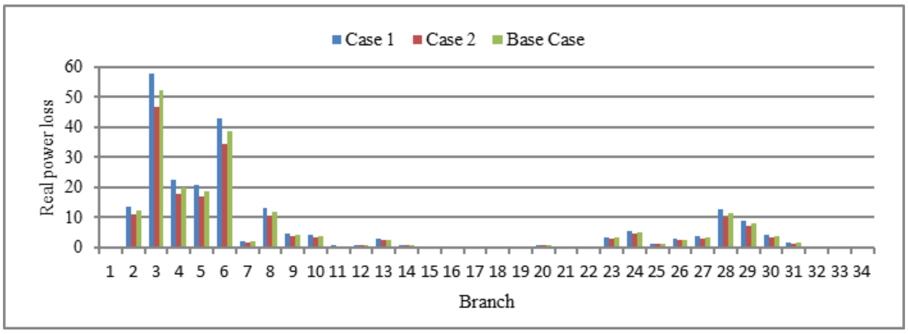

Figure 6. Real Power Loss Profile of 33 Node RDS

Figure 7 depicts the influence of Case 1 and Case 2 on the reactive power loss profile in contrast to the Base Case for 33 node RDS.

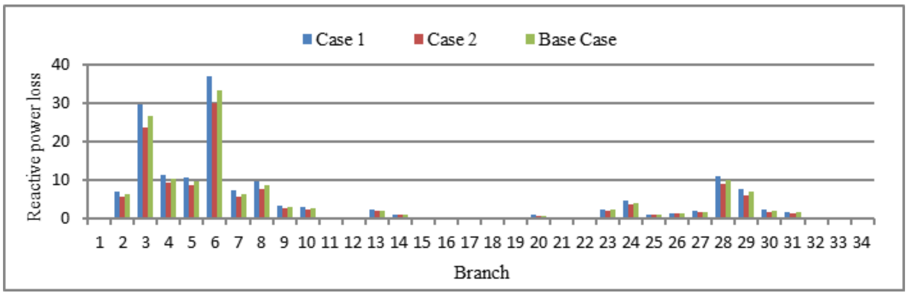

Figure 7. Reactive Power Loss Profile of 33 Node RDS

6. Conclusion:

This paper gives a brief overview of various methods for distribution system load flow analysis, including deterministic and probabilistic methods. The system where there is uncertainty in the line and load data is not suitable for the deterministic approach. Sincere attempts were undertaken in this article to take the uncertainty in the load data into account, and a modified algorithm based on B/F sweep was evaluated on an IEEE-33 Bus system. The findings demonstrate how uncertainty impacts the system's voltage profile, losses, and loading.

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