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Hybrid Optimization Algorithms for Locating and sizing a Local Power Generation Source with combination of Deregulated problems for a Radial Structured Distribution Network

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Power networks in India are extensive and intricate. The government, transmission companies, and distribution companies have challenges in managing the intricate network under the existing regulatory framework concerning cost, efficiency, and reliability. This is the rationale for the government's advocacy for power sector deregulation. The integration of local sources into the distribution network is one of the concepts of deregulation. This study presents a potential process consisting of three steps. Phase one, This paper presents a unique model for finding the best place for distributed generators (DGs) to improve the efficiency of a radial distribution system (RDS) with loads that stay the same in terms of power and impedance. The model accounts for factors such as actual power losses as well as the sizes and positioning of the distributed generators necessary to meet the load demand. We use self-regulating, efficient algorithms based on actual data to determine the size and placement of the DG. The proposed approach evaluates the sizes and positioning of distributed generators (DGs) via a modified pathfinder optimization algorithm (MPFO), the Hybrid Red Fox Path Finder Algorithm (HRPFO), and a hybrid Teamwork-Teaching Learning Optimization Algorithm (TTLOA). In the second phase, integrating distributed generation (DG) and

network reconfiguration may improve network performance. Still, the large number of options, including non-radial network configurations, makes it harder to choose the right size and placement of distributed generation while also reconfiguring the network. Using five different cases that illustrate various outage scenarios, we assess the proposed model in the third phase to confirm its validity. The findings show that the suggested model could greatly improve network performance by changing the layout and size, position of distributed generation. We implemented the suggested strategy on the IEEE 33 Test Bus and contrasted the outcomes with traditional methods.
Keywords: Deregulations, LS-Local source, MPFO-Modified pathfinder, RDS-Radial distribution system, RFO-Red fox optimization, Hybrid Red Fox Path Finder Algorithm (HRPFO hybrid Teamwork-Teaching Learning Optimization Algorithm (TTLOA), GA–Genetic Algorithm

1. Introduction

Electricity supply systems must constantly progress due to a population increase, growing urbanization, and digitalization of many industries driving an increasing demand on power. These intricate networks which include production, distribution, transmission, and utilization are the basis of contemporary civilization and allow for anything from industrial electricity to residential illumination. They have to nevertheless conquer obstacles to meet the increasing demand while preserving effectiveness, dependability, and ecological responsibility. Renewable energies such as solar and wind power are currently being integrated into electrical grids, which is a major revolution in the energy sector. There are benefits and drawbacks to this switch to energy from renewable sources. Although renewable energy sources are more environmentally friendly and long-lasting than conventional fossil fuels, grid management may become more challenging due to their unpredictable and sporadic nature [1]. Furthermore, the infrastructure for distribution and transmission needs to be updated and expanded in order to meet the increasing demand for power.This work seeks to tackle these problems and have a positive impact on a more resilient and sustainable future by optimizing inside the power grid. We may work to increase the power grid's general resiliency, effectiveness, and dependability by improving [Specific Region]. This will make it easier to integrate sources of renewable energy and guarantee the safe and dependable transmission of energy for consumers. This chapter provides a detail explanation about electrical power systems, Radial Distribution Networks (RDN) in power systems, ReConfigural Networks (RCN) in power systems.

DG allocation in electrical power systems, optimal placement in electrical power systems and loss in electrical power systems. Few recent literatures have done related to this work and find some gap between the existing related works is discussed in Table .1.

Table 1: Research gap about optimal DG placement

Ref no	Technique	Advantages	Limitations
[2]	Quasi-Oppositional Chaotic Symbiotic Organisms	Improves the distribution of DG in the radial system	Exclusive to networks with radial dispersion
[3]	Hybrid approach	Combines several DG kinds	Difficulty rises when there are more kinds.

[4]	Spotted Hyena Optimization Method	Takes grid and dispersed production into account	Implementation complexities of the algorithm
[5]	Positioning and Size Concurrently	Concurrently maximizes the capacitor's capacity and DG	Highly sophisticated
[6]	Student Psychology-Based Optimization Algorithm	Innovative strategy motivated by philosophy	May need to be adjusted for various issues
[7]	Dual-Setting Direction Over-Current Relay Devices: Optimum Synchronization	Takes into account the transient stability encountered in multi-source mesh networks.	Intricacy rises as the network's complexity does.
[8]	Better Wild Horse Optimizing Process	Effective DG management based on dependability	Limited scope
[9]	Improved GSA and Reactive PSO for Multi-Objective Modifications	Makes use of adaptive optimization techniques	A rise in the complexity of computing
[10]	Bat Optimization Algorithm	Manages the best distribution of DG allotment	It is dependent on setting parameters
[11]	Binary particle swarm optimization and shuffled frog leap	Applying SLFA or Binary PSO techniques	The implementation difficulty

After the find the above gaps next extended the literature and find some more gaps related to DG placement issue with combination some more deregulated problems like reconfiguration of the network and some outages scenario Those problems are listed below. In table 2.

Table 2: Research gap about optimal DG placement combination with deregulated problems.

Ref No	**Technique**	**Advantages**	**Limitations**
[12]	Salp Swarm Algorithms	Upgrade the Effective distribution of sustainable resources	It could be necessary to adjust the settings for specific circumstances.
[13]	Management of Active Energy Loss	Supports different weight estimates	DGs Bigger networks may lead to a rise in intricacy.
[14]	Optimizing Artificial Bee Colony	Performance manages capacitor distribution and multifaceted reconfiguration of networks Sensitive to variable values	more computing effort might be needed
[15]	Ideal Feeder Reorganization and DG Positioning	offers the best options for DG location and feeder adjustment	Inadequate scalability for expansive networks
[16]	Feeder Reorganization using capacitors	A Multifaceted Approach takes into account optimal DG sizing, system reorganization, and power security	When there is more than one goal, complexity rises.
[17]	Reconfiguring the Network and Using Several DG Units	Minimizes power loss by moving numerous DGs and reconfiguring the network	Possible difficulties in combining several DG units
[18]	Concurrent Network Reorganization and Capacitor Positioning	It improves performance by placing capacitors and reconfiguring simultaneously	When more gadgets are integrated, complexity could rise.
[19]	Butterfly Booster Butterfly optimization	It is used in a multifaceted strategy to get the best DG connectivity and network reconfiguring	Optimization performance has a significant impact on efficiency.
[20]	Utilizing D-STATCOM and PV Technology,	Meta-heuristic Method Reconfigures networks using PV & D-STATCOM	There could be difficulties integrating various dispersed energy resource types.
[21]	Optimized Metaheuristic Approach for Network Reorganization	Concurrent reconfiguration of the network and distribution of DG	Performance can change depending on the specific setup and features of the network

2. Work Objective

The suggested study aims to optimize DG placement, hence improving the efficiency and reliability of RDN. This is achieved by using a full-function objective that simultaneously improves the profile of voltage and decreases power consumption(P_loss). By taking goals, constraints including power balance, voltage constraints, DG size boundaries, and network reliability problems into account, the study aims to lower loss rates as well as increase the stability of voltage. The most egalitarian way to regulate voltage between bridges is accomplished by using continuous voltage swings as an indicator statistic. The goal of the project is to provide energy system designers as well as managers with helpful options by allocating loss through proportional share and sophisticated optimization approaches. In the end, the approach leads to lower losses of power, greater effectiveness, as well as increased dependability when using RDS. When assigning the DGs, the constraints and goal functional formulation must be carefully considered. Lowering this $P\_(loss)$ in the structure and enhancing the voltage distribution for the buses using sufficient weighting ought to be the main goals of the optimal solution problem's goal function. It is essential to minimize the accumulated voltage variation at each bus to accomplish this objective. to compute overall CVD, which is a measure of a voltage profile's change. Thus, when tackling the DG allocating issue, it is crucial to thoroughly describe the end goal functions and restrictions.

It is possible to achieve lower power expenses, better stability of voltage, greater supply accuracy, and better network performance by combining DG deployment with system modification. The objective function stands bound by particular limitations as stated and contains two objectives that are balanced appropriately. Both of these restrictions have to be fulfilled to reach the limited acceptable value for an identified goal variable. To identify the most effective approaches, all of these restrictions need to be met at the same time.

2.1Objective function

Allocating Local source requires careful attention to the definition of the objective function and restrictions. The objective function of the optimization problem should focus on reducing the P_{loss} in the system and improving the voltage profile of the buses with appropriate weighting. To achieve this goal, minimizing the cumulative voltage deviation (CVD) at each bus is critical. The CVD is calculated using equation 1 and serves as an indicator of the improvement in the voltage profile. Therefore, it is important to carefully model the objective function and constraints when addressing the problem of local source allocation.

$$\mathrm{CVD} = \begin{cases} 0 & \text{if } 0.95 \le |V_m| \le 1.05 \\ \sum_{m=1}^{N_b} |1 - V_m|, & \text{else} \end{cases} \quad (1)$$

The objective function has two goals that are weighted accordingly, and it is subject to specific constraints as given below

$$\text{Minimise}\left\{\omega.\frac{\sum_{m=1}^{nl} P_{loss}(m)|_{wLS}}{\sum_{m=1}^{nl} P_{loss}(m)|_{woLS}} + (1-\omega).\frac{\mathrm{CVD}|_{wLS}}{\mathrm{CVD}|_{woLS}}\right\} \quad (2)$$

To achieve the minimum value of a given objective function, certain constraints must be adhered to, including both equality and inequality constraints. These constraints must be satisfied simultaneously in order to find the optimal solution.

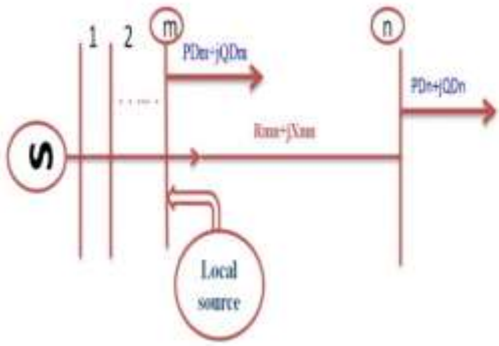

Fig. 1. Radial portion between nodes m and n

2.2 Power balance

The P and Q power balance is given in eqns (3) and (4)

$$P_{slack} + \sum_{m=1}^{N_{LS}} P_{LS,m} = \sum_{m=1}^{N_l} P_{D,m} + \sum_{m=1}^{nl} P_{loss}(m) \quad (3)$$

$$Q_{slack} + \sum_{m=1}^{N_{LS}} Q_{LS,m} = \sum_{m=1}^{N_l} Q_{D,m} + \sum_{m=1}^{nl} Q_{loss}(m) \quad (4)$$

2.3 Bus voltage limits

To guarantee a steady and reliable supply, the network must maintain an acceptable voltage profile. The voltage threshold is provided by

$$|V_{min}| \leq |V_m| \leq |V_{max}|, \quad m\forall N_b \quad (5)$$

2.4 Local source sizing limits

$$P_{LS,min} \leq P_{LS,m} \leq P_{LS,max}, \quad m\forall N_{LS} \quad (6)$$

$$PF_{LS,min} \leq PF_{LS,m} \leq PF_{LS,max}, \quad m\forall N_{LS} \quad (7)$$

$$Q_{LS,m} = P_{LS,m}.\tan\left(\cos^{-1}(PF_{LS,m})\right) \quad (8)$$

2.5 Maximum level of Local source penetration

The total power generated by local source must be limited to a certain degree of implementation in order to preserve network stability and avoid problems brought on by over generation.

$$\sum_{m=1}^{N_{LS}} P_{LS,m} \leq \mu \,.\sum_{n=1}^{N_l} P_{D,n} \quad (9)$$

The term "penetration" refers to the ratio between the power generated by local sources and the total load demand of the power system. It is given by Eqn. (10)

$$\mu = \frac{\sum_{m=1}^{N_{LS}} P_{LS,m}}{\sum_{m=n}^{N_l} P_{d,n}} \quad (10)$$

2.6 Network active power loss

Local sources should reduce overall system losses compared to a scenario without local source

$$\sum_{m=1}^{nl} P_{loss}(m)|_{wLS} < \sum_{m=1}^{nl} P_{loss}(m)|_{woLS} \quad (11)$$

3. Minimization Function

3.1. Loss Sensitivity Factor (LSF)

The LSF is given by

$$LSF(n) = \frac{\partial P_{mn-loss}}{\partial P_n} \quad (12)$$

$$= \frac{2P_n}{|V_n|^2} . R_{mn}, \; n\forall\{2 \ldots\ldots N_b\}, m\forall\{1, \ldots (N_b - 1)\} \quad (13)$$

3.2 Voltage stability index

The distribution system usually has a radial structure, where buses that are further away from the substation experience more voltage drop and are more prone to voltage collapse. Therefore, VSI is utilized to determine the most vulnerable buses to voltage collapse.

$$\boldsymbol{VSI = |V_m|^4 - 4(P_nX_m - Q_nR_m)^2 - 4(P_nR_m + Q_nX_m)\,|V_m|^2} \quad (14)$$

Local source should be installed in the busses that show the greatest suitability values based on both voltage indications and Line Stability Factor (LSF). Due to their reliance on network circumstances, load, and configuration, LSF assessments might not always be accurate.

4. Proposed Approach

4.1 DG allocation for radial distribution system through optimal sizing in radial power distribution network.

As shown in figure 2 ,A new method for selecting DG in the optimal places of networks of distribution is proposed to minimize $P\_(loss)$.

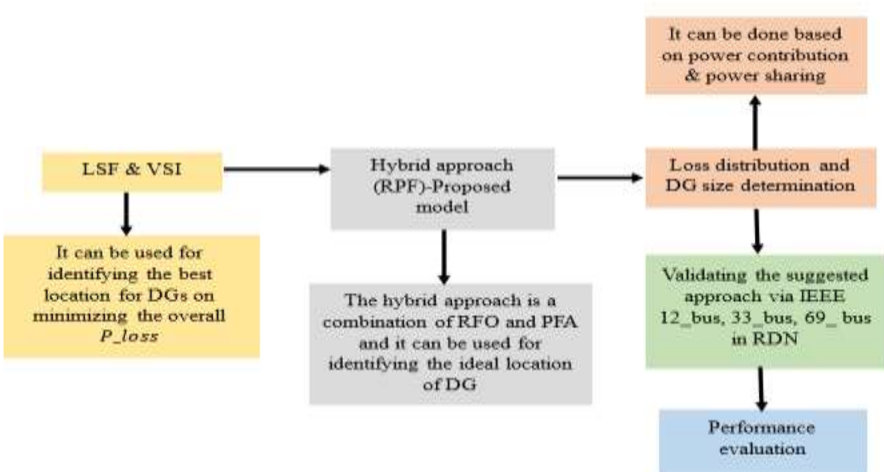

Figure:2: Overall architecture of the suggested approach

Utilizing powerful metaheuristic optimization methods along with equitable pooling to distribute loss, the method addresses a nonlinear optimization issue. Given equitable and unequal constraints, the optimum spot among the DGs is determined by minimizing the total $P\_(loss)$ using the LSF as well as VSI. Red Fox Pathfinder Optimization (RPO), an innovative hybrid optimization approach, is employed to determine the optimal position for the DG (PFA) using Red Fox Optimization (RFO) together with the Pathfinder Algorithms. The optimal DG dimension is established after the spot has been chosen, as well as power contributing and share of power matrices are used to distribute the loss across the DGs. The proposed method will be assessed on the IEEE 12,BUS , IEEE 33_bus,IEEE 69 BUS RDS to confirm its viability. The results will be compared with alternatives that are currently in use. The benefits associated with the positioning of DG include a reduction in P_(loss), an increase in effectiveness, a boost in dependability, and an electric field improvement. Moreover, the architecture of the suggested approach can be illustrated.

4.2 Optimal Placement of Distributed Generators and Distribution Network Reconfiguration for Loss Reduction: Validation on Multiple Test Bus Systems And Outage Scenarios

To reduce loss within networks of distribution, the present study presents a novel method that combines two main techniques: optimum placement of DGs along distribution network reconfiguration (DNR). It aims to reduce the general loss of the structure yet maintain its operational limits by modeling the DNR and determining the correct size and positioning of the DGs as an optimization issue. To address this problem, this study project will present the Teamwork-Teaching-Learning optimization (TTLOA) approach, a new hybrid optimization approach. The traditional Teamwork Optimization Algorithm (TOA) as well as Adapted Teaching–Learning–Based Optimization (TLBO), accordingly, are hybridized into the suggested TTLOA paradigm. Four distinct power system—the IEEE_33 bus will be used for testing the suggested technique to assess it. The suggested approach has been tested with five distinct situations, each of which represents a distinct interruption scenario, to guarantee its reliability.

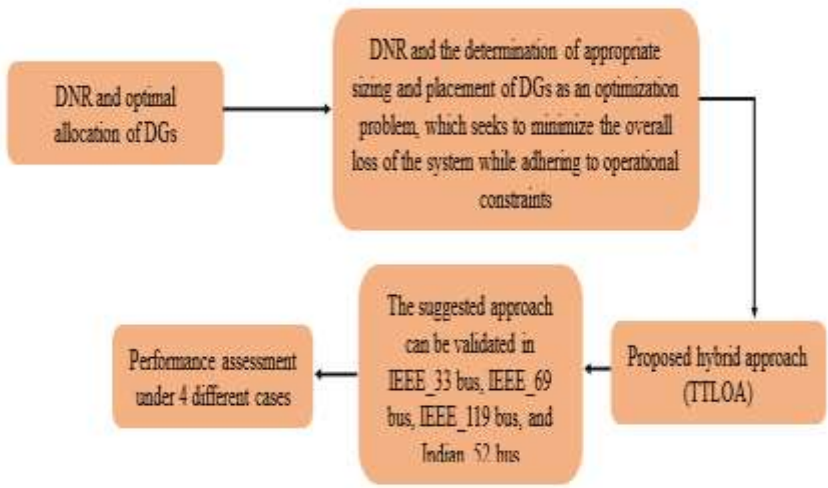

Figure: 3: Architecture of the suggested approach

The overall architecture of the suggested model can be given in Figure 3. Case 1 deals with bus failures that are caused by malfunctions that cause buses to become unplugged off the rest of the network. Case 2 illustrates how cable failures, both symmetrical as well as uneven, can cause line interruptions. In Case 3, bus therefore lines failures are going to happen simultaneously, as well as the system will be assessed under those conditions. Case 4 addresses DG outages, which result in power fluctuations whenever generators fail to provide the necessary amount of power because of inefficient input. The efficacy of the suggested approach will be evaluated by transferring the various cases for each of all four bus networks. To lower the general network reduction, the simulator will take operating limitations into account and seek ways to reduce entire system loss. The suggested technique will offer a practical means of simultaneously optimizing these two strategies to lower distribution network degradation.

5. Result and discussion

The IEEE-33 BUS system taken as a test system and applied all proposed approaches and compared in the graphical representations as well as tabulations related to these were also provided.

Analysis of power loss is one of the prime noted areas where the IEEE 33-bus system stands out. In distribution networks, most of the losses occur due to resistance in lines as electricity flows from substations to consumers. The IEEE 33-bus system, with a radial configuration, suffers naturally more than meshed systems on longer branches. Researchers often use this system in testing optimization techniques that aim to reduce the power losses in active and reactive powers, which subsequently maximizes energy efficiency. Some common applied and benchmarked methods for the system include network reconfiguration, which changes the topology of the system to reroute power flow, and capacitor placement, which enhances the voltage profiles as well as reduces the reactive power demand.

Further, with the increased penetration of distributed generators, such as solar panels and wind turbines, into the grid, this IEEE 33-bus model has proven highly valuable in analyzing the penetration of distributed energy resources into the electrical grid. When properly integrated into the network, DGs may offer such as localized generation that reduces the power needed to be supplied by the central substation, thus lowering line losses and improving voltage stability. When DGs are introduced in a radial system, it makes the integration procedures difficult because coordination in preventing reverse power flows and ensuring proper system stability is required. The IEEE 33-bus system can present a proper environment for testing various strategies and schemes for DG placement to ensure optimum performance in terms of low losses and reliable operation. The IEEE 33-bus system is a very important tool for studying electrical distribution networks with considerations on power losses, voltage regulation, and integration of distributed generation. The radial configuration of the distribution model helps provide a similar real-life model to find the problems encountered in real-world systems like voltage drops and line losses. A comparison between the IEEE 33-bus system and other IEEE test systems makes it easy to understand the characteristics of distribution networks and thus create solutions for the improvement of efficiency and reliability. Since such a system has been extensively used for academic and industrial research work, it has become the standard benchmark for new methodologies, optimization algorithms, and grid management techniques being tested concerning modern power distribution systems.

Table :3: Performance analysis of IEEE_33 bus system

	HRPO	PFO	RFO	GA	TTLOA	TOA	TLBO	PSO
Active Power Loss	139.740 9	140.287 5	140.62 66	146.802 1	123.5159	127.9351	129.9713	131.3406
Reactive Power Loss	92.3173	94.1325	97.016 8	101.683 2	81.5963	85.6912	86.6028	92.582
Number of DG	2	2	2	2	2	2	2	2
Optimal DG Location	23 14	30 32	14 17	16 33	32 17	10 16	14 31	32 29
Optimal DG Size P KW	22 455	377 332	430 286	388 325	476 80	494 199	267 417	291 255
Optimal DG Size Q KVar	10.6550 9 220.366 6	182.589 4 160.79	208.25 85 138.51 61	187.917 157.404 7	230.5373 38.74577	239.2551 96.3801	129.314 201.9623	140.9377 123.5021
Minimum Voltage	0.92618	0.89456	0.8874 8	0.87885	0.93123	0.88592	0.88057	0.85833
Minimum Voltage Bus Number	33	18	33	31	18	33	18	18
Maximum Voltage	0.99742	0.98176	0.9158 4	0.90148	0.99749	0.98034	0.97605	0.90313
Maximum Voltage Bus Number'	2	2	2	2	2	2	2	2

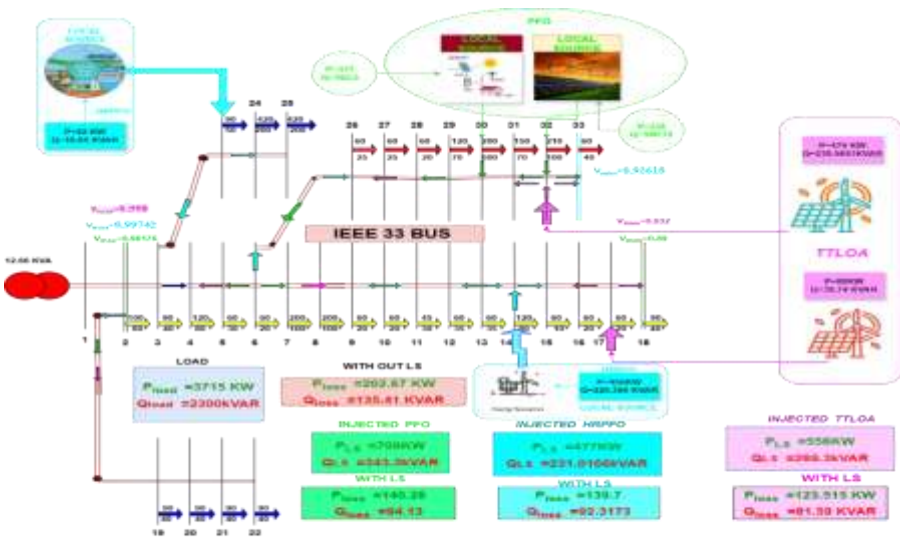

Figure: 4: single line diagram of 33 bus radial system including local source placement using Algorithms

Table 3 as well as figure 4 shows the comparison of the different optimization techniques used on the IEEE 33-bus system, which contains optimization techniques in their form such as HRPO, PFO, RFO, GA, TTLOA, TOA, TLBO, and PSO. The comparative study has been made on three objectives: active and reactive power losses, optimal Distributed Generator placement, and voltage characteristics. Findings from this table have been given below for the reflection of variations in the performance of the system with the applied optimization method. The magnitude of power loss varies a lot with the methods used. TTLOA shows the lowest active power loss with 123.5159kW. Its next alternative is the TOA method, which shows 127.93kW. This makes both of them far better in terms of reducing power losses in the network. It can be seen that RFO and GA have more active power losses, which are 140.62 kW and 146.8 kW, respectively, so these techniques are less efficient in terms of reducing losses. Also, it can be found that TTLOA has reactive power loss lesser than 81.5963kVAR, whereas for GA and RFO, reactive power losses are the highest with the values of 101.6832 kVAR and 97.0168, respectively. The number and locations of the optimal DGs are quite different among the above methods. For instance, HRPO allocates the DGs to buses 23 and 14, and GA allocates them to buses 16 and 33. TTLOA locates the DGs in buses 32 and 17 with larger generation capacity, which seem more evenly and intensively distributed with 476 kW and 80 kW, respectively. This helps to minimize the line losses, which is self-evident in the results. On the other hand, the GA with DG sizes of 388 kW and 325 kW at buses 16 and 33 has a higher power loss, thus representing the importance of optimal placement and sizing with the minimum possible loss. The minimum and maximum bus voltages also differ for both methods. TTLOA provides a minimum voltage of 0.93825 mV in bus 18, which informs that TTLOA is good for maintaining better voltage stability within the network. GA and PSO own minimum voltages of 0.87428 and 0.8586, respectively, which may lead to poor voltage regulation and instability within the network. Maximum voltage is fairly uniform across all the techniques, while values of HRPO and TTLOA are closer to 1.0; therefore, the profile of voltage throughout the network is relatively smooth. TTLOA, therefore, emerges as the best technique in terms of achieving minimum loss in P loss and Q loss in the network while maintaining good stability in the network voltage, followed by TOA. HRPO and PFO are more or less acceptable but with more loss compared to TTLOA. GA, RFO, and PSO, although optimal for DG placement, incur more losses with the lowest voltage stability. Hence, it appears that these algorithms fail for the given network system. For this purpose, an optimization technique needs to be chosen properly to optimize the IEEE 33-bus distribution network.

5.2.1 Comparison of Minimum Voltage

The lowest voltage level which is observed at any bus in the operation of the system usually occurs at buses furthest along in the line due to the effects of line impedance and reactive power demand. In this radial distribution system, the voltage drops are influenced by the load demands, lengths of lines, and a lack of supportive devices to affect the voltage. Optimal placement of Distributed Generators can result in improved voltage profiles significantly by reducing the load demand from the substation. Some are achieved by the method TTLOA with a higher value of the minimum voltage obtained, which is 0.93517 p.u., meaning the voltage is far more stable. Others, such as PSO, have lower minimum voltage values, that is, 0.86524 p.u., which means that their regulation of voltages is less efficient.

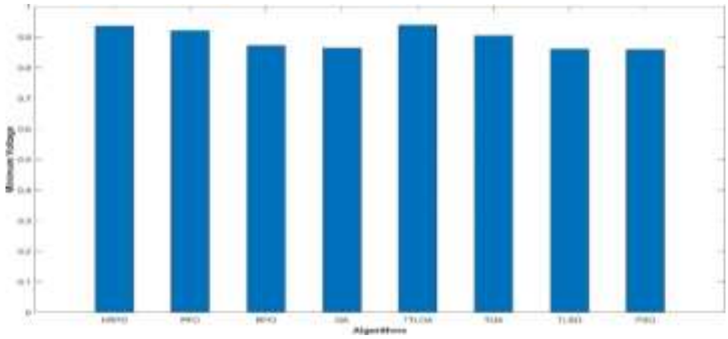

Figure 4: Comparison of minimum voltage in IEEE_33 bus system

The following bar graph shows the minimum voltage values achieved by various optimization algorithms in the IEEE 33-bus system. The x-axis provides the following algorithms: HRPO, PFO, RFO, GA, TTLOA, TOA, TLBO, and PSO. The y-axis for the minimum voltage ranges from 0 to 1 per unit. The above graph shows that the concept of voltage stability across the distribution network also deserves importance because higher minimum values assure better voltage regulation and system performance. From the above figure 4, it is observed that TTLOA shows the maximum voltage, approximately 0.9978 p.u. It means in the IEEE 33-bus system, this algorithm will perform quite well in voltage stability performance. Both the results of HRPO and PFO are good enough, nearly up to the minimum voltage values of 0.99 p.u. and 0.98 p.u., respectively. On the contrary, algorithms like GA, TLBO, and PSO have minimum voltage values between 0.85 p.u. and 0.87 p.u., which indicates that these techniques are not fully viable to ensure stability in the network level of the voltage within the network. A minimum voltage higher value as close to 1.0 p.u. is desirable since this means that the drop across the system is minimized; buses in the network can load and meet demands independently. TTLOA can reach a higher value of the minimum voltage, indicating that the placement of DG is optimally designed so that power losses are minimized and voltage profiles are improved. On the other hand, the observed smaller minimum voltage values for GA, TLBO, and PSO indicate these methods are not more efficient than others in controlling voltage drops and may cause poor voltage stability or even suboptimal performance at some places of the network. Graph 5.1 reveals that a huge performance gap was situated between the different algorithms. TTLOA was found to maintain the best performance in keeping a steady voltage profile, followed by GA, TLBO, and PSO, which need improvement. The results prove that the selection of an optimization algorithm plays a significant role when improving voltage stability within a network, with very close relevance to maintaining minimum levels of voltage in systems like the IEEE 33-bus system.

5.2.2 Comparison of Maximum Voltage in IEEE_33 bus system

Maximum voltage in the IEEE 33-bus test system is an important parameter for analyzing performance and stability measures of electrical distribution networks. In this standard model designed to accommodate testing and benchmarking algorithms applied to the distribution system, maximum voltage levels are naturally associated with the location of the highest demand loads or the closest buses of the substations with the highest voltage regulation capability.

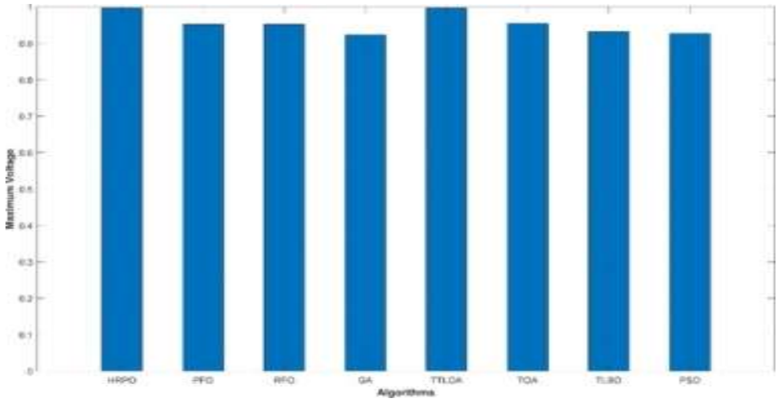

Figure 5: Comparison of Minimum voltage in IEEE_33 bus system

The IEEE 33-bus system, with its different types of loads and configurations, is widely analyzed under various operating conditions, based on profiles for voltage, losses, and compensation strategies of reactive power. The voltage levels in a power distribution system should be within specified limits to ensure that the system is operated reliably. Under such circumstances, possible problems such as a voltage drop and overloading of equipment must be prevented. The above bar graph figure 5 compares the performance of various optimization algorithms in terms of maximizing the voltage levels in an electrical power system. Along the horizontal axis, corresponding algorithms appeared - HRPO, PFO, RFO, GA, TTLOA, TOA, TLBO, and PSO, and on the vertical axis, the maximum voltage acquired is represented. HRPO and TTLOA appear to be the best algorithms, showing the maximum values of voltage. It could indicate that these techniques are more efficient in optimizing the power system to achieve a better voltage profile. PFO, RFO, GA, TOA, and TLBO attained very good performances and close maximum voltage value to the best one achieved by HRPO and TTLOA. PSO is relatively poor compared to all other algorithms and therefore may not be able to make effective maximization of the voltage levels in this scenario. The performances of these algorithms are expected to vary based on their respective capabilities for exploring search space, convergence speed, treatment with constraints, and uncertainties. Because of having various strengths in HRPO and TTLOA, they might outperform all others in the maximization of voltage levels. One possible reason for their success is that both HRPO and TTLOA are adaptive to the dual process of exploration and exploitation. Exploration is concerned with discovering new solutions that may potentially better solve a problem while focusing on improving a better solution found so far, called exploitation. A good balance between the two leads to the avoidance of getting stuck in local minima and finding a global optimal. There is also much to be learned about the specific mechanisms by which HRPO, TTLOA, and the other more modern optimization techniques contribute to power system voltage optimization. For instance, the impact of different system parameters, changes in loads, and operating conditions on the performance of these algorithms could be explored. A possible further direction is hybrid approaches in which the best characteristics of two different algorithms are utilized, which may lead to even better results.

5.2.3 Active power loss in IEEE_33 bus system

Techniques such as the Newton-Raphson or Gauss-Seidel method can be adopted to calculate active power loss in the IEEE 33-bus test system through load flow studies. The basic elements influencing the overall active power loss in the system are the resistance of the distribution lines and the currents passing through them, as given by the formula . The total active loss in the IEEE 33-bus system is usually estimated to be around 210 kW when a load flow study is carried out. This value shows the system's performance and hints where improvement can be made to further minimize losses in the context of the system configuration or how the optimum power should flow into the system.

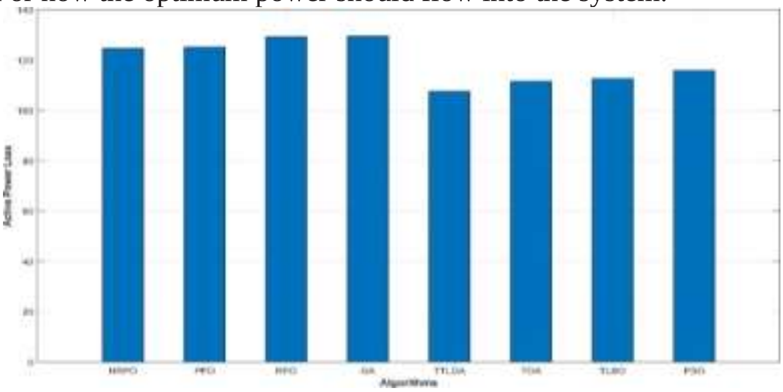

Figure 6: Active power loss in IEEE_33 bus system

Presented here is a bar chart figure 6 showing performance comparisons of optimization algorithms for loss in the active power of an electrical power system. In the horizontal axes, different algorithms are presented: HRPO, PFO, RFO, GA, TTLOA, TOA, TLBO, and PSO, while the active power loss was carried on the vertical axes. The best-performing algorithms are HRPO, PFO, and RFO, which experienced the smallest value of active power loss. These kinds of results indicate that the above-mentioned methods are excellent candidates to optimize a power system with fewer energy losses. GA, TTLOA, TOA, TLBO, and PSO also performed well, but still with rather higher active power losses as compared to HRPO, PFO, and RFO. The performance differences among different algorithms may be attributed to the fact that they have been able to explore the search space, their convergence rates, and how they address constraints as well as uncertainties. Most probably, the difference in performance in terms of loss reduction inside active power will make these algorithms, HRPO, PFO, and RFO, exceptional on these issues. One possible reason why HRPO, PFO, and RFO work is that balance exploration and exploitation during the optimization process. Exploration refers to searches for new and possibly better solutions, while exploitation refers to refinements on existing solutions. With a balanced approach, algorithms might therefore avoid being trapped in local optima and find the global optimal solution. Understanding the mechanism behind the effectiveness of HRPO, PFO, RFO, and other advanced optimization techniques can be achieved by showing ways to gain a profound understanding of mechanisms at work behind these various optimum power flow programs while studying the susceptibility of system parameters of different load variations and other operating conditions for these algorithms. Hybrid approaches will be possible combining the benefits of different algorithms for even better results.

5.2.4 Reactive power loss in IEEE_33 bus system

The reactive power loss in the IEEE 33-bus test system is also analyzed through load flow analysis similar to the calculation of active power loss and would depend upon the reactive power demands of the loads and characteristics of the distribution network. The primary source of reactive power losses is the line reactance and the current flowing through the lines. This is quantified through the expression: , where is the reactive power loss, is the current, and Is the line reactance. Typically, in the IEEE 33-bus system, the total reactive power loss is approximately 70 kVAR, which might suggest the support of reactive power to potentially enhance voltage stability, and even reduce losses through the integration of reactive power compensators or optimized voltage control strategies.

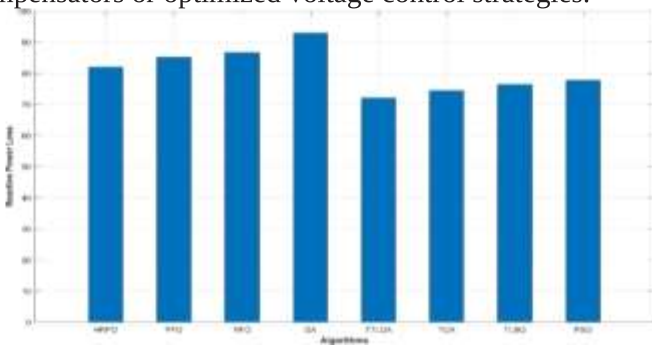

Figure 7: Reactive power loss in IEEE_33 bus system

The following bar chart figure 7 describes the comparison of different optimization algorithms for the minimization of reactive power loss in the electrical power system. The abscissa provides the names of the algorithms considered in the examination: HRPO, PFO, RFO, GA, TTLOA, TOA, TLBO, and PSO; the ordinate represents the reactive power loss. HRPO, PFO, and RFO once more give the lowest reactive power loss. This indicates that these are the optimum methods to be applied in the power system where both active and reactive losses in power are involved. GA, TTLOA, TOA, TLBO, and PSO show other potential algorithms with higher levels of reactive power losses as compared with the above results. These factors include the search space exploration capability, convergence rate, and ability to deal with constraints and uncertainties. This is the main reason why HRPO, PFO, and RFO are better in these aspects and thus successful in minimizing reactive power loss. This could be the reason why these algorithms may be able to work, as they not only explore but also maintain exploration-exploitation equilibrium. Exploring new and perhaps better solutions happens in one instance while exploitation is when the refinement of solutions is in place. Such a balanced approach assists algorithms from getting stuck at some local optima and then achieving global optimal solutions. Further study and investigation of HRPO, PFO, RFO, and other advanced optimization techniques for loss reduction in the power system are necessary to have an in-depth knowledge of the particular mechanisms associated with the effectiveness of those techniques. This could be done by analyzing the impact of different system parameters, load variation, and operating conditions on the performance of those algorithms. Hybrid approaches that take the strengths of different algorithms together may also be explored for improved results.

6. CONCLUSION

To reduceP_(loss), an innovative approach for choosing the best locations for DG with the distribution systems is presented in this research. The method allocates loss using strong metaheuristic strategies for optimization along with equitable distribution; to find the optimal site of DGs whilst reducing overall P_(loss), both the LSF & VSI are implemented. Red Fox Pathfinder Optimisation (RPFO), an innovative hybrid optimization technique, integrates the Pathfinder Algorithm (PFA) as well as Red Fox Optimization (RFO) to identify the ideal spot of DG. The suggested approach's viability is evaluated using IEEE 33_bus RDS, & the outcomes are contrasted with those of other approaches already in use. According to the study, there are several advantages to using the suggested strategy for placing DGs, such as lower P_(loss) as well as request, increased reliability and effectiveness, and superior power characteristics. As the amount of DGs increases, the power loss decreases. Power contributions and allocation of power parameters are used to determine the ideal DG number and loss allocation across DGs. The suggested method provides a practical and cost-effective way to position DGs, which can reduce energy loss while improving the functionality of the networks that distribute electricity. Energy system designers as well as operators will discover a useful tool in the suggested Optimization model, which makes it easier to identify the best places for DG. In the next part of research work was found one new optimization algorithm which wills deals multiple situations. The study has shown that the Hybrid TTLOA model is a promising approach for simultaneous DNR and optimal placement of distributed generators for loss reduction. The model has been tested and validated on multiple test bus systems, under various outage scenarios, demonstrating its robustness and effectiveness in diverse conditions. The implementation of the TTLOA method in MATLAB has resulted in significant reductions in power loss and improvements in voltage profile when four DGs are connected, as well as the optimal placement of distributed generators. A comparison with other existing methods has also confirmed that the proposed model outperforms in terms of reducing P_loss and Q_loss and improving the voltage distribution. Therefore, the Hybrid TTLOA model provides a promising solution for improving the efficiency and reliability of distribution networks.

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