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ANALYSIS OF LARGE SCALE DISTRIBUTION NETWORK USING WHALE OPTIMIZATION ALGORITHM

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ABSTRACT

In this study, we use a loop matrix to describe the reorganisation of the RDN's formulation. Calculation time is increased when an optimum reorganisation is determined analytically. More network buses means more time to calculate. Therefore, a technique of optimisation is required to determine the best reorganisation of the radial distribution system. The optimum reorganisation aims to reduce network losses to a minimum and the voltage profile is enhanced. Loop matrices are used to describe the re-formulation of the radial distribution system. The analytical technique of identifying optimum reconfiguration involves additional calculation time. The computational complexity grows as the system's bus count rises. Therefore, a search for the best possible radial distribution system reconfiguration necessitates an optimization technique. The ideal reconfiguration focuses mostly on reducing the system's overall loss. The genetic algorithm (GA), particle swarm optimization (PSO), and whale optimization algorithm (WOA) are the optimization methods used in this paper. Two test systems consisting of 119 buses, and 135 buses are used to evaluate the effectiveness of various optimization strategies. The outcomes are then compared with one another.

Keywords: load flow, losses, radial distribution network (RDN), particle swarm technique, whale optimization algorithm (WOA).

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1. INTRODUCTION

Consumers' reliance on electricity is rising rapidly. Population growth, excessive loads, and appliances with a poor power factor are to blame. As a result, the distribution network experiences an increase in power losses (I2R) and voltage drop as a result of the combined impacts of these variables. To solve these issues, the distribution network must be restructured. Changing a distribution's topology via reorganisation preserves its radial structure. It's one of the least expensive ways to reduce network losses without installing compensatory equipment. Changing the topology in such a way as to reduce losses is referred to as an optimum RDS reorganisation. The number of RDS loops is the main factor in determining how many tie-line switches should be used. In this part, we looked at how to determine the optimal combination of main buttons and tie line buttons. The purpose of optimisation is to restructure networks such that they incur less loss. Therefore, in this chapter, a heuristic method is utilised to determine the best times to open and close switches to minimise the amount of energy wasted by the network. The loop matrix (LM) buttons tie connections and compartmentalized switches.

Loss mitigation is the primary use case for the reconfiguration. Load planning and power network designs go into making the RDN. However, daily network use grows. As a result, the higher demand is met by the already designed distribution infrastructure, although with greater losses. As network demand increases, the network's losses decrease. This results in network losses. The reorganisation altered the layout of the anticipated distribution network as demand grew. Theoretical investigations into the bigger picture of lattice redesign have been created, but there is still a need for more suitable and successful solutions for lattice reorganisation in the context of stable operating circumstances. Load-flow analyses and studies for commercial and industrial power grids were suggested [1]. It was also discussed how to undertake a contemporary load flow study with the use of computer-aided analysis software and what features should be included. This strategy takes a lot of effort and time. The power flowing through the lines may be calculated using several different load flow techniques, some of which were explored by Gilbert *et al.* [2]. They looked at all three approaches and found that Distflow performed the best overall. The suggested strategy will not make functions easier to choose. MATLAB simulation software was used to study load flow studies and the Gauss-Seidel and Newton-Raphson Methods for four-bus networks [3].

They concluded that Newton Raphson was better than Gauss-Seidel. [4] prioritise optimum feeder design by altering tie and sectionalising switches while keeping the lattice's radiality intact; they use the PSO method to determine the optimal switching pattern. Studying the 33 bus route system. As a result, Dhal *et al*. [5] developed a strategy for drastically rearranging the Radial Distribution Network (RDN) to alter the power flow through the lines. In RDN, simultaneous switch flipping is achieved with the help of the Whale Optimisation Algorithm (WOA). The Fast Decoupled Method was then described by Stott, B., and Alsac [6], which is a straightforward, dependable, and lightning-fast approach to resolving load flows. Gauss-Seidel concept explanations for load flow analysis control for large power network stability were provided by Eltamaly *et al.* [7]. This is shown with the help of a case

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study of a five-node network. After performing simulations on a 33-bus network, Dahalan *et al.* [8] introduced an efficient technique based on Particle Swarm Optimisation (PSO) to determine the switching operation plan for feeder reorganisation, contrasting the results with those obtained using the Genetic Algorithm. An effective mathematical model for reorganising radial distribution networks and minimising power loss was presented and evaluated by Mahdavi.M and Romero [9] for 16, 33, 69, 70, 119, and 135 bus networks. Using Particle Swarm Optimisation (PSO), [10] understand the network reconfiguration issue, reduce losses, and enhance the voltage profile in a Radial Distribution System (RDS). The approach was validated on 33, 69 bus networks. Particle Swarm Optimisation (PSO) was utilised by [11] to optimise the voltage profile and decrease losses in a network with 30 buses. Then, Salomon *et al.* [12] suggested utilising the PSO method for load flow predictions and validated their proposal with numerical tests on a six-bus network. Active power losses in a 6-bus network were reduced using the PSO method [13]. Adjusting the method's settings results in an approximately 19% loss reduction. Then, Patil *et al.* [14] suggested using a PSO algorithm to simulate the performance of power networks with 14 and 30 buses, to minimise the cost of fuel consumed in generating while still satisfying the load demand. The magnitude and phase angle between the voltages is calculated using a load flow analysis, which may be performed using Artificial Neural Networks (ANN), Ant Colony Optimisation (ACO), Ant Bee Optimisation (ABO), or Particle Swarm Optimisation (PSO) as suggested by Jaiswal *et al.* [15].

Motivated by a need in the literature, this study seeks to fill it by making methodological contributions to the reduction of RDS loss via reorganisation, the discovery of a methodology for formulation using optimisation methods, and the analysis of large bus distribution networks that mimic real distribution networks. The remainder of this article is organised as follows: The optimum reorganisation analysis and load flow analyses are discussed in Part 2. In section 3, the suggested method is presented. The results of numerical and simulated analyses of the 119 and 135 bus networks are explained in part 4.

2. LOAD FLOW STUDIES

Any analysis of an electrical system should concentrate largely on load flows. In load flow evaluations, variables such as voltage, current, phase angle, losses, and conductor limits are figured out. As part of the load flow analysis, we take into account the generator bus, slack bus, and load bus. To calculate the currents between two nodes, the forward/backward sweep approach may be used in conjunction with the voltage of the buses in the forward direction and the impedance between the nodes in the reverse direction.

2.1 Forward and Backward Sweep Method

Node voltages and distribution losses are first calculated using load flow studies as part of the distribution network study. The majority of experts in the area agree that the backward-forward sweep method is the best for analysing power flows in balanced radial distribution systems. Kirchhoff's current law is used to estimate the current in the reverse direction, whereas Kirchhoff's voltage law is used to estimate the voltage at the nodes in the forward direction. Figure-1.1 depicts a radial network with'mn' nodes.

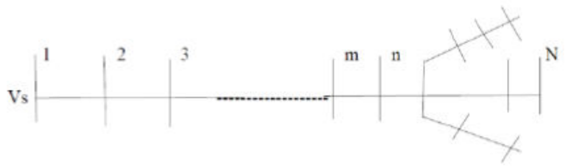

Figure-1. Branching radial network with the value'mn'.

Take N to be the total number of nodes.

Bus 1 is supposed to have a voltage of Vs=0.

First, all voltages and bus voltages are set to their initial values.

Vj^((0))=V_S∠0 For j=2, 3..., N (1)

Second, set the number of repetitions, k, to 1.

Third, determine the currents of load at each bus. For each j=2, 3,...., N (2), Ij((k))=((PLj+jQLj)/(Vj((k-1)))*

Fourth, sweep backward

Node-to-node branch current calculation

There are mn nodes in the network, hence Imn((k))=In((k))+(all the current branches stemmed from bus N) mn. (3)

Action 5: Sweep In Front

The voltage at each bus, from the starting node to the destination, was calculated.

Iteration k voltage on bus n Vn((k)). The expression Vm((k))-Zmn Imn((k)) for j=2,3,....N (4)

Sixth, get the error at each bus by solving: ej((k))=Vj((k))-Vj((k-1)) for j=2,3,....N (5)

Following this, we get to Step 7: e $_{max}$((k))=max(e_2((k)),e_3((k)),......eN((k)) (6)

Here we have Step 8: e max (k) (your chosen tolerance value). (7)

If you're happy with the results, go to Step 9.Unless you want iteration k to equal k+1, change it. Proceed to PHASE 3 now.

The load distribution patterns of a radial distribution network with six buses are analysed.

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The latest tally: By rearranging the preceding equation, we can get the load current at bus-n, which

represents the injected power for the bus-n complex: Sn =Pn + jQn = Vn* In* (8)

This may be expressed as ILn = ((Pn + jQn)/Vn)* = (Pn - jQn)/((Vn*)) (9)

At the values of 1, 2, 3,..….
What is the current load at node n?
Pn = Injectable Active Power at Node-n
Qn = Node-n's Phantom Power Injection
Vn = node-n's voltage on the bus

2.2. Analysis of Optimal Reorganization

The best RDS reorganisation is the one that reduces losses relative to the current losses to a minimum. Minimising network losses is the objective function used to determine the best way to rearrange RDS resources.

$$f_{obj1} = \min \sum_{lm=1}^{nbranch} TL_{lm} = \sum_{lm=1}^{nbranch} V_{lm}^{*} I_{lm} \quad (10)$$

Where TL represents RDS losses, lm represents the branch connecting the lth and mth buses, V_{lm} represents the voltage on the l_m^{th} branch, n branch represents the number of branches, and I_{lm} represents the current flowing via branch l_m.

3. WHALE OPTIMIZATION ALGORITHM

WOA is an algorithm motivated by swarm-based techniques and inspired by nature. Swarm-based development is predicated on a central premise: the exploration of potential food sources. Comparable to the crowded parts of the new and renovated city is the area around the restaurant. Due to their daily piercing movements for the food, however, no two swarm stages are ever the same. Dragons are also depicted as operators in WOA, able to recognize the difference between areas and common enemies based on where they can find food. Words like "adepts," "top-most productions," "division," "art," "union food supply," and "enemy" are all used in WOA.

3.1 Algorithm and Flow Chart

Enclosing the prey, using a bubble net hunting technique, and searching for it are the three main components of the WOA mathematical model. Figure-2: The Bubble-net Search Mechanism used by WOA. The flow chart of WOA for optimum reconfiguration is Figure-3. Table-1 displays the values that were entered into WOA's parameters.

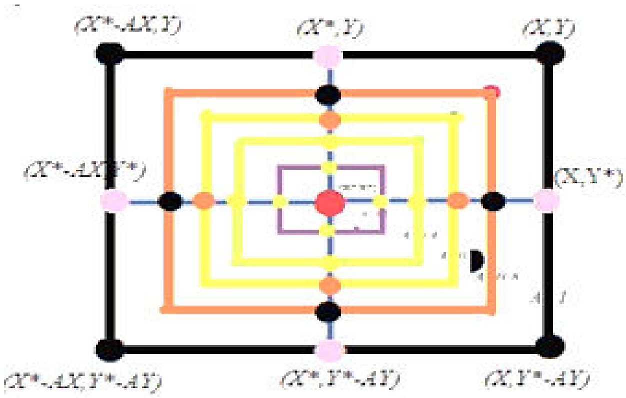

Figure-2. Bubble-net Search Mechanism employed in WOA.

Step1: The initial number of search agents equals 100, with a maximum of 500.

Step 2: Limits must be established by setting minimum and maximum values and determining appropriate dimensions. The limits of a configuration change are the radial distribution bus's branch numbers.

Step 3: Perform the basic load transfer to determine I^2R loss and voltages before optimization.

Step 4: Start position vector at zero and leader score at infinite. Create a random whale position X. X(i) = ran(SA, dim)*(ub-lb)+lb when b=l. X(i) = ran(SA,1)*(ub-lb)+lb when b>l.

Step 5: For each repetition, reform a, A, C, l, and p.

$(i,j) = (j) - A*(X) if A \geq 1$ (14)
$(i,j) = Leader - (j) - A*(l) if A < 1$ (15)

Step 6: Check whale boundaries in the search space and relocate them as necessary.

Step 7: To imitate humpback whales' helix-shaped movement, a spiral equation links the whale's location to the prey's.

$(t + 1) = Debt \cos(2 * pi * l) + X* (t)$ (16)

Step 8: Humpback whales swim in a spiral and a decreasing circle around their prey. Whale positions are adjusted via the shrinking encircling mechanism or spiral model during optimization.

$(t + 1) = \{X* (t) - A.Dif p < 0.5 \}$
$(t + 1) = \{Debt \cos(2 * pi * l) + X* (t) if p \geq 0.5\}$

Step 9: Update each search agent's location during exploitation using a randomly selected search agent rather than the best one.Exploration and | A | > 1 allow the WOA algorithm to search globally.

Step 10: Iterate steps 6–9 until the iteration count hits 0 or an optimal solution is found.

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Step 11: Present the whale's leader score, which yields the lowest power loss for the leader position, or a set of best switches for low loss.

Table-1. Parameter values used for WOA.

S. No.	Name of the parameter	Value
1	Crossover	0.65
2	Prey	0.45
3	Iterations	500
4	Searching Agents	100

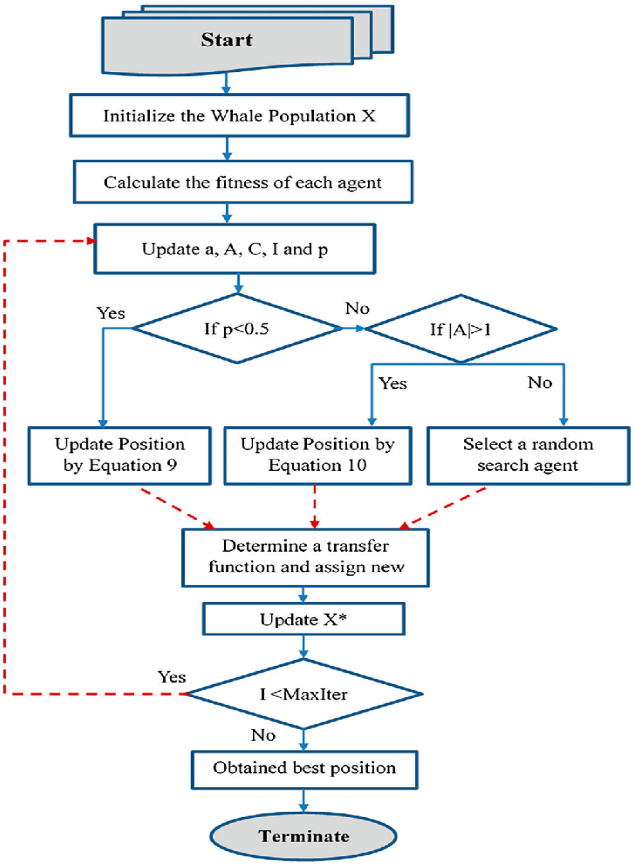

Figure-3. Flowchart of optimal reconfiguration using WOA.

4. RESULTS AND DISCUSSIONS

The 119 bus and 135 bus RDS systems are used to validate the suggested technique. Depending on the system type, the optimization method will have different parameters. The extent to which optimization methods may be used is proportional to the number of variables being considered. Here, we're interested in the bus system's total number of tie-line switches.

4.1 Test-1-119-Bus System

These suggested methods are used for the analysis of a radial distribution system with a large load and bus size. There are fifteen tie-line switches in the bus system. The radial distribution system of 119 buses may be improved with the use of these switches. From the 119th bus to the 134th branches, there are a total of 134 tie-line switches. Figure-4 depicts the WOA-enabled system reconfiguration for a total of 119 nodes. The 119-bus system's three tie-line switches and other compartmentalized switches are optimized with the help of the GA algorithm. The tie-line switches that are utilized to optimize the RDS are 121, 129, and 130. There is a drop from 1150 kW to 809 kW in the system's losses. The PSO employs the 123, 130, and 131 tie line switches for optimizing the system. As a result, 793 kW in losses have been eliminated, with another 779 kW eliminated for WOA due to the 122, 130, and 131 tie-line branches. Table-2 displays the results of the system comparison. The voltage profiles of 119 bus RDS are compared and contrasted with the suggested optimization strategies in Figure-5. The true power losses of many algorithms are shown in Figure-6.

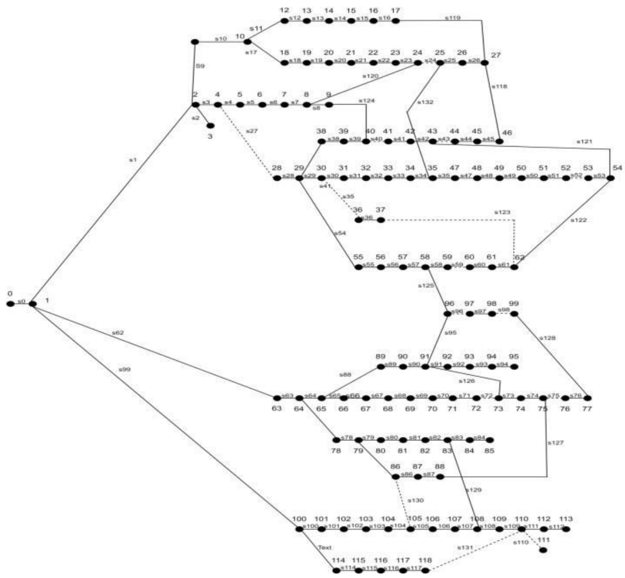

Figure-4. 119- Bus system reconfiguration using WOA.

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Table-2. A comprehensive optimization study comparing 119 bus system parameters.

	Devoid of reconfiguration	GA	PSO	WOA
Switches open	118-132	42 25 23 121 50 58 39 95 71 74 97 129 130 109 34	24 27 35 40 43 52 59 72 75 96 98 110 123 130 131	24 26 35 40 43 51 59 72 75 96 98 110 122 130 131
Losses (kW)	1150.102	809.001	793.120	779.001
% Reduction of losses	---	29.57	30.14	32.15
Minimum voltage(p.u)	0.892	0.941	0.952	0.960

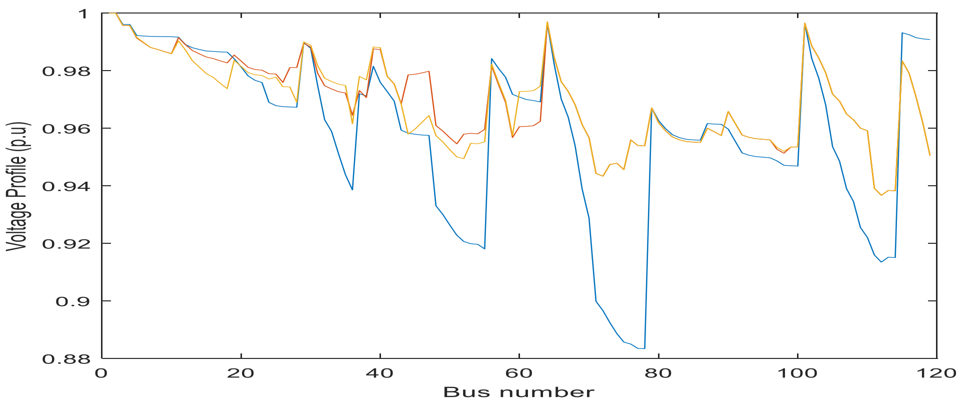

Figure-5. Analyzing the voltage profiles of a 119-bus system and contrasting them with optimization strategies.

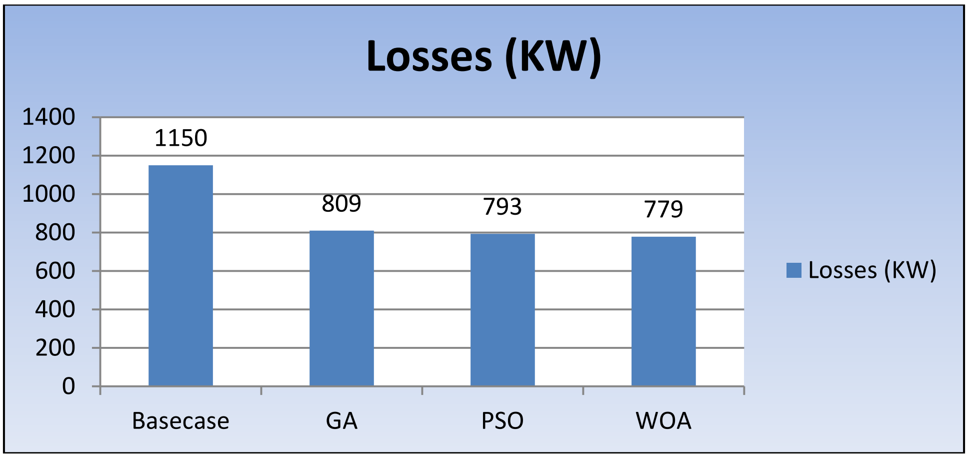

Figure-6. 119 bus system real power losses using various algorithms.

4.2 Test-2-135-Bus System

These suggested methods are used for the analysis of a radial distribution system with a large load and bus size. The bus system is equipped with 21 tie-line switches. The 135-bus radial distribution system benefits from these switches, which are employed for system optimization. From the 134th bus to the 156th branches, they are the numbers of the tie-line switches. Figure-7 depicts the WOA-enabled system reconfiguration for 135 nodes. The 135 bus system with 16 tie line switches and 5 sectionalized switches is optimized using the GA method. The tie-line switches that are utilized to optimize the RDS are 121, 129, and 130. From 306 Kw to 285 kW, the system's losses have decreased. The PSO employs the 123, 130, and 131 tie line switches for optimizing the system. Hence the system is optimized with the reduction of losses of 281 kW whereas for WOA these losses are decreased further 275 kW with the 122, 130, and 131 tie-line branches. Table-3 displays the results of the comparative examination of the system. Figure 8: Voltage profile comparison for 135 bus RDS using suggested optimization methods. Figure-9 demonstrates the true power losses of several algorithms.

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Table-3. A comparative study of a 135-bus system.

Method	Switches open	Voltage profile	Real power losses (kW)
Devoid of reconfiguration	136-156	0.9380	306.010
GA	141 146 116 150 34 94 144 138 139 137 154 152 155 149 148 145 153 143 147 151 128	0.9540	285.102
PSO	7 35 51 90 96 106 118 126 135 137 138 141 142 144 145 146 147 148 150 151 155	0.9520	281.011
WOA	51 53 90 96 106 118 136 137 138 139 141 144 145 146 147 148 150 151 154 155 156	0.9630	275.010

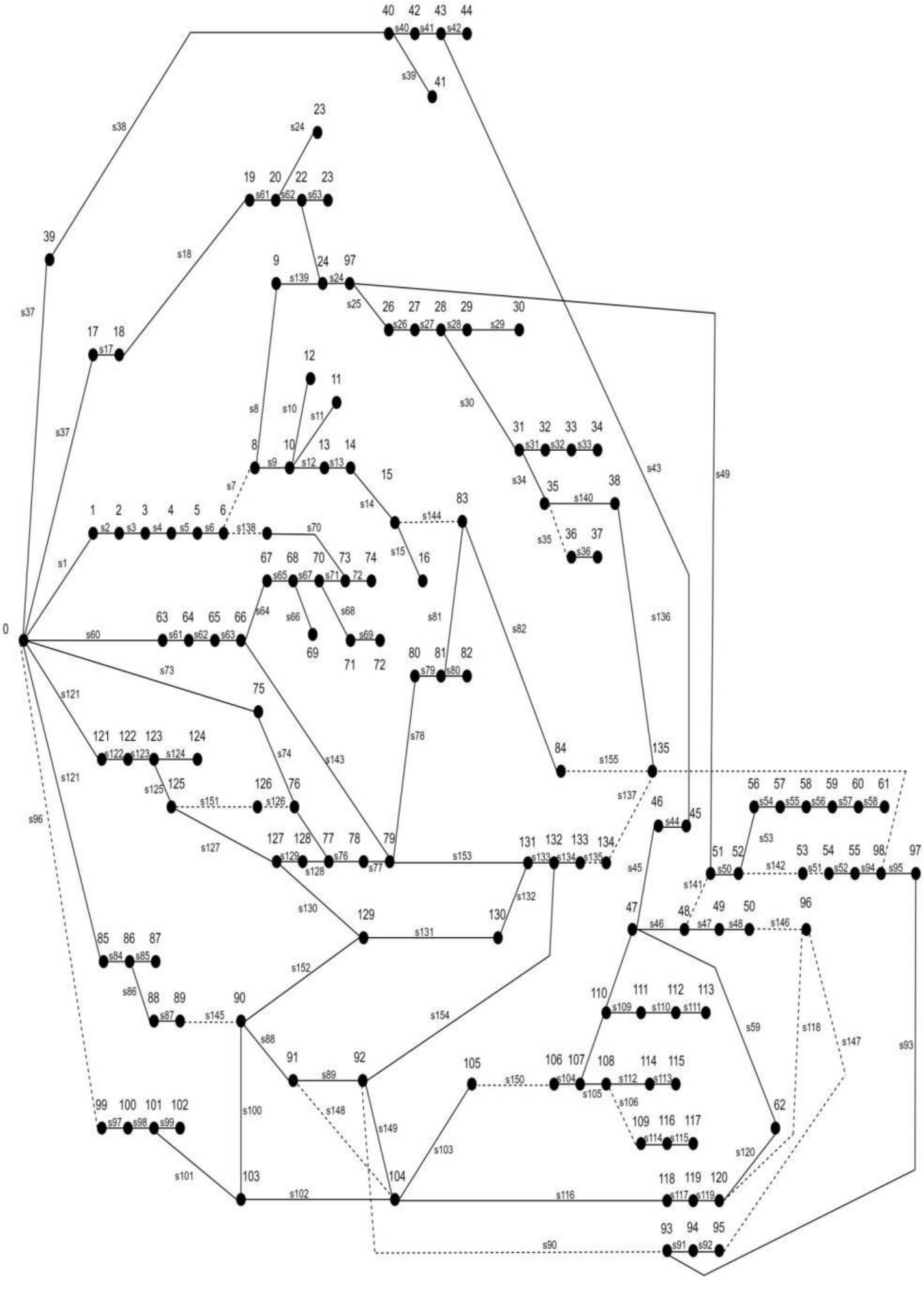

Figure-7. 135- Bus system reconfiguration using WOA.

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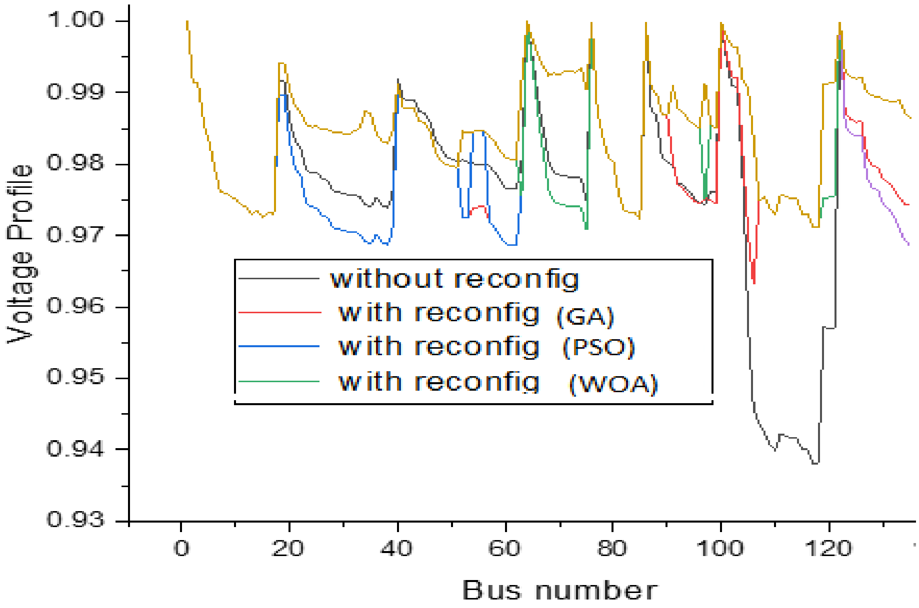

Figure-8. Analysis of 135-bus system voltage profiles using various optimization methods.

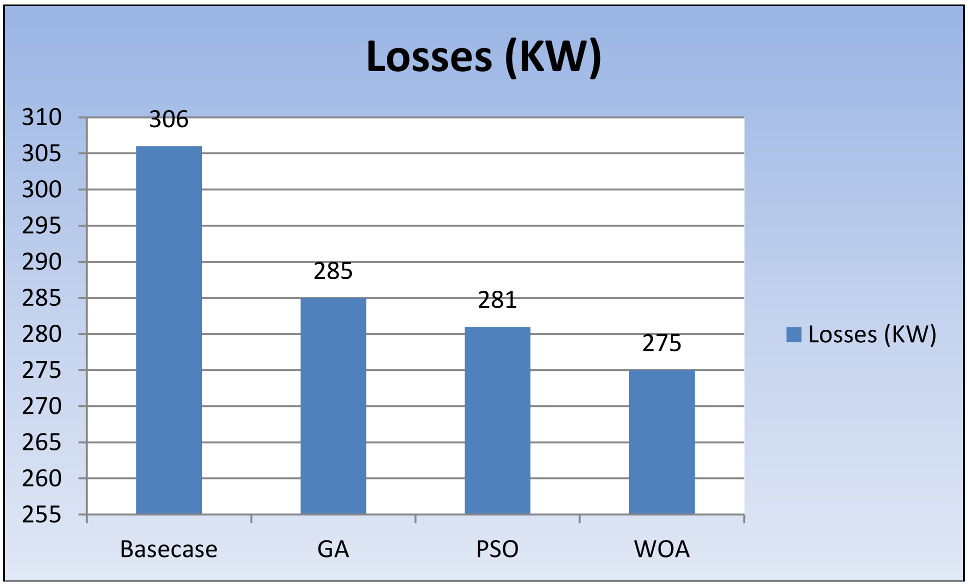

Figure-9. 135 bus system real power losses using various algorithms.

5. CONCLUSIONS

Optimisation algorithms like GA, PSO, and WOA are used to find the most efficient routes for buses 119 and 135. When the 119 and 135 bus networks are reorganised using PSO optimisation, there are fewer losses. Since the 119 bus network has generated 15 loops through 15 tie-line switches, the issue dimensions are 15. The 135 bus system's 21 loops are connected by tie-line switches. The WOA algorithm provides the most advantageous rearrangement. In this piece, we look at how simultaneous switching may be used to reorganise traditional distribution networks. When compared to GA, PSO, and load flow techniques for solving identical distribution networks, Whale Optimization's usage for reorganisation results in significant reductions in both power losses and computing time. Reorganisation may cut losses by as much as 779 kilowatts (KW), or about 32.5%, for a network of 119 buses, and by as much as 306.01 kilowatts (KW) and 275 kilowatts (KW) for a network of 135 buses. The reorganised data reveals the suggested Whale Optimisation technique may use many switches simultaneously to find the optimal solution.In this study, WOA gives the best optimal reconfiguration solution. The real power losses are for 119bus 779.01kw and 135bus 275.01kw.The voltage profile enhanced from 0.938 pu to 0.9630 for 135 nodes and 0.892 to 0.96 pu for 119 node system.

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