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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. Genetic algorithm (GA) and particle swarm optimisation (PSO) are the optimisation methods employed in this piece. In this piece, we look at how meta-heuristic optimisation may be applied for efficient rearranging. For the purpose of rearrangement, we use organic optimisation techniques such as the PSO approach. We describe and analyse the reorganisation issue in a typical large-scale 119 and 135-node network under both optimisation and non-optimization conditions. The outcomes are then compared with one another.

Index Terms- Load flow; losses; Radial distribution network (RDN); Praticle swarm technique; Whale Optimization Algorithm (WOA).

I. 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. In order 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 switches and tie line switches. The purpose of optimisation is to restructure networks such that they incur less losses. Therefore, in this chapter, a heuristic method is utilised to determine the best times to open and close switches in order to minimise the amount of energy wasted by the network. The loop matrix (LM) controls the switching of tie lines and compartmentalised switches.

Loss mitigation is the primary use case for the reconfiguration. Load planning and power network design 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 by J.J. Dai and Shokooh [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 a number of 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 proposed method will not ensure easy pickings for any functions. Load flow studies and the Gauss-Seidel and Newton Raphson Methods for solving load flow equations for a four-bus network in MATLAB simulation software were explored by Chatterjee, S., and Mandal [3].

They came at the conclusion that Newton Raphson was better than Gauss-Seidel. Shetty, V.J., and Ankaliki, [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 study of a five-bus system. 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), Reddy, A.S., and Reddy [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 Widarsono et al. [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 by Abugri et al. [13]. Adjusting the algorithm'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, with the aim of minimising the cost of fuel consumed in generating while still satisfying the load demand. The magnitude and phase angle between the voltages are 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 provided in Part 2. In section 3, the suggested algorithm is shown. The results of numerical and simulated analyses of the 119 and 135 bus network are presented in section 4.

II. LOAD FLOW STUDIES

Any investigation of an electrical grid should focus primarily on load flows. Voltage, current, phase angle, losses, and conductor limitations are all calculated in load flow assessments. The generator bus, slack bus, and load bus are all used in the load flow analysis. The forward/backward sweep technique is an algorithm for determining the currents between two nodes by using impedance between the nodes and voltage in the opposite direction, with the voltage of the buses in the forward direction.

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.

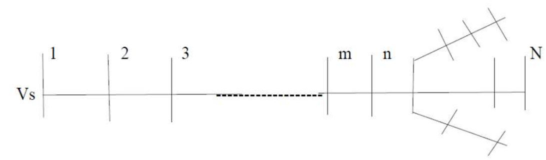

Fig 1. Branching radial network with the value'mn'

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.
V_j^((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), I_j((k))=((PL_j+jQL_j)/(V_j((k-1)))*
Fourth, sweep backwards
Node-to-node branch current calculation
There are mn nodes in the network, hence I_mn((k))=I_n((k))+(all the current branches stemmed from bus N) (3) mn.
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 V_n((k)). The expression V_m((k))-Z_mn I_mn((k)) for j=2,3,....N (4)
Sixth, get the error at each bus by solving: e_j((k))=V_j((k))-V_j((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)),......e_N((k)) (6)
Here we have Step 8: emax(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.
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. 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.

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

where TL represents RDS losses, lm represents the branch connecting the lth and mth buses, Vlm represents the voltage on the lmth branch, n branch represents the number of branches, and Ilmis represents the current flowing via branch lm.

III. PROPOSED METHOD

Particle using the analogy of random birds looking for food, Particle Swarm Optimisation (PSO) is a metaheuristic optimisation technique. Each bird is treated as a discrete unit of analysis. The global best is selected by updating the local best of each particle's location and velocity at each iteration, and the particles are then anticipated to converge on the global best.Particle swarm optimisation (PSO) is employed since it has been shown effective across many fields of research and technology, and because the necessity for optimum reorganisation was indicated in the previous section. Using a swarm intelligence model, PSO optimises the hunt for food. Figure 2 is a PSO flowchart depicting the optimum reorganisation process.
These are the steps of the PSO algorithm:
First, we'll do some setup.
Set the starting locations and velocities for each particle in the radial network to be picked from.
Step 2: Physical Health Assessment
Use the fitness function to determine a particle's score. Select the particle with the highest fitness as the gBest.
The formula for gBest is: gBest = min(XtBEST,i).
Third, each particle's velocity and location are updated.

Apply the following formulas to each particle to update its velocity and location.
Vijk+1 = wVijk + c1rt1j[XtBEST,i - Xtij] + c2rt2j[GtBEST,i - Xtij] Xit+1 = Xit + Vit * T (11)
Fourth, modify the fitness worth.
Updated fitness values may be calculated by re-entering the new velocity and new location into the fitness function. It's time to update the gBest, so t = t+1.
The Iterative Process, Step 5
Repeat steps 2, 3, and 4 until the current iteration count reaches the maximum value, t.
Phase VI: Result

After a certain number of rounds, the outputs gBest and Xti that provide the optimal reorganisation pattern with minimal power losses are retrieved.

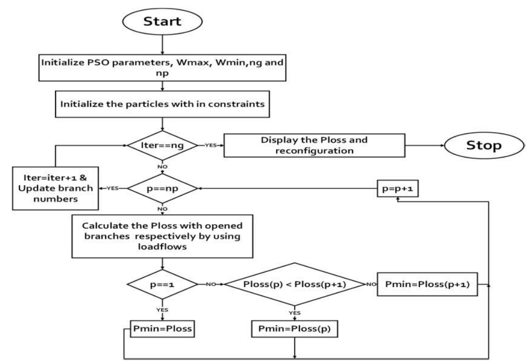

Fig.2 Schematic depicting PSO's optimum reorganisation

IV. RESULTS AND DISCUSSION

Case-I: 119-RDN

1. Devoid Reorganization

Fig. 3 depicts the 119 bus's voltage distribution.15 tie-line switches are used in the 119 bus network. The voltage profile's sags and spikes reveal how many sub laterals are present in a given network. Bus 1 branches off onto three more lines: bus 2 and lines 63 and 100. Drops in voltage may be seen on Buses 1, 2, 62, and 100. 119 bus RDS has actual power losses of 1298.01 kW.

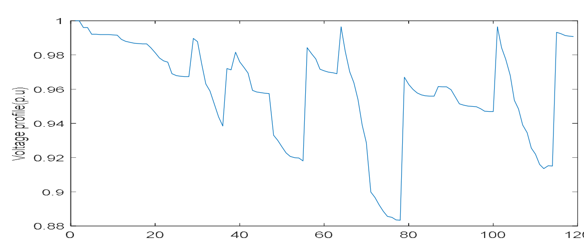

Fig.3 Network voltage distribution over 119 buses

2. With Reorganization

15 tie-line switches are used in the 119 bus network. The losses amount to 848 kW, and the number of switches involved in the reorganisationis:43,120,24,51,49,6240,126,74,73,77,83,31,110,35. As can be seen in fig.4, the voltage profile has been enhanced as a result of the reorganisation of the 119 bus network.

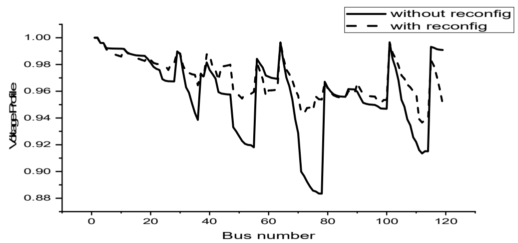

Fig. 4 The revised voltage diagram for the 119 bus system.

3. Using PSO for Effective Reorganisation

High-rated RDNs, defined as those with a high-rated load and bus size, are the focus of the suggested algorithms' research. There are fifteen tie-line switches in the bus system. The radial distribution network of 119 buses may be improved with the use of these switches. From the 119th bus through the 134th branches, there are a total of 134 tie-line switches. Figure 5 depicts the PSO-driven reorganisation of the 119-node network. Using three tie line switches and various compartmentalised switches, the GA algorithm is used to optimise the 119-bus network. Tie-line switches 121, 129, and 130 are used to get optimum RDS performance. There is a drop from 1150 kW to 809 kW in the network's losses. To get the most out of the network, the 123, 130, and 131 tie line switches use the PSO. As a result, 793 kW of losses have been eliminated, making the network more efficient. Voltage profiles of 119 bus RDS and suggested optimisation strategies are compared and contrasted in fig.6, and the results of this comparison are shown in Table 4.6. The true power losses of many methods are shown in Figure 7.

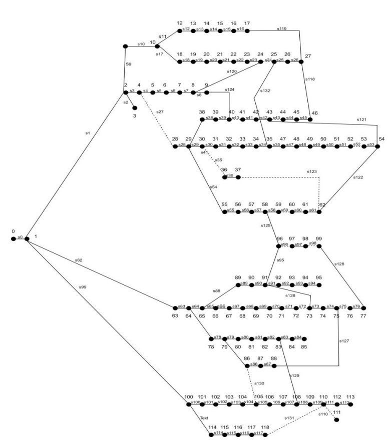

Fig.5 PSO-based network redesign for a fleet of 119 buses.

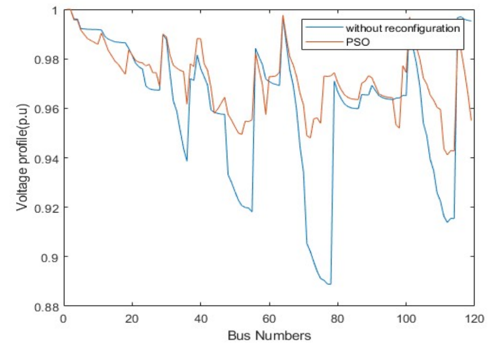

Fig. 6 A voltage diagram of the 119-bus network after PSO-based reorganisation.

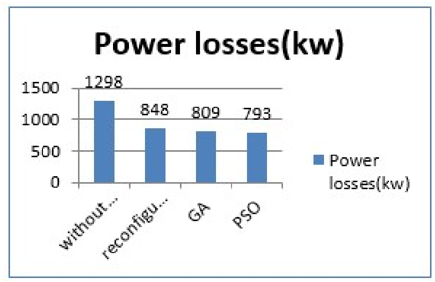

Fig 7. Impact of algorithmic watt losses

In Table I, we can see the results of an optimisation study comparing 119 different parameters in bus networks.

Table I. Optimisation methods are used to compare 119 different bus network characteristics.

Content	Without reorganization	With reorganization	GA	PSO
Switches open	118 119 120 121 122 123 124 125 126 127 128 129 130 131 132	43 120 24 51 49 62 40 126 74 73 77 83 31 110 35	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
Losses (kW)	1298	848	809	793
%Reduction of losses	---		29.57	30.14
Minimum voltage(p.u)	0.892	0.935	0.941	0.952

Case-II: 135-RDN

1. A. Devoid Reorganization

Fig.3 depicts the 135 bus's voltage distribution. The 135-bus network has 21 tie-line switches. The 135 bus RDS actual power losses are 306.01 kW.

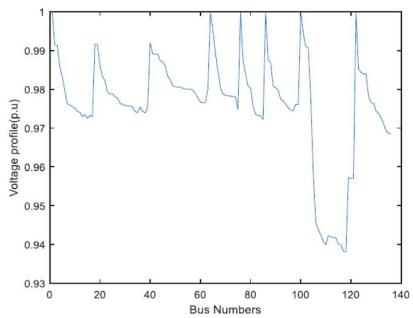

Fig.8 Network voltage distribution over 135 buses

2. With Reorganization

The 135-bus network has 21 tie-line switches. Total losses amount to 288.02 kW, and the reorganisation switches are as follows: 141,146, 116, 150, 34, 94, 144, 138, 139, 137, 154, 152, 155, 149,148, 145, 153, 143, 147, 151, 128. Fig..9 displays the enhanced voltage profile as a result of the 135 bus network's reorganisation.

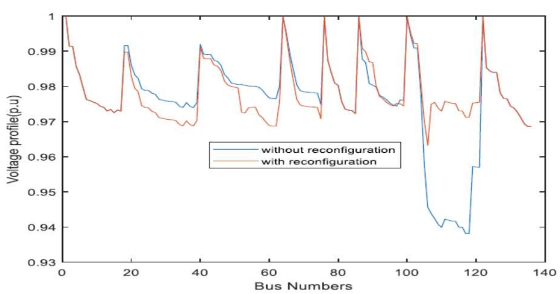

Fig.9 Network voltage diagram after rearranging 135 buses

2. Using PSO for Effective Reorganisation

High-rated RDNs, defined as those with a high-rated load and bus size, are the focus of the suggested algorithms' research. The bus system comprises 21 switches that connect lines. The 135-bus radial distribution network functions best with these switches enabled. Figure.10 depicts the PSO-driven network reorganisation involving 135 nodes. 7 35 51 90 96 106 118 126 135 137 138 141 142 144 145 146 147 148 150 151 155 are the optimal tie-line switches for RDS optimisation. There has been a drop from 306.01 kW to 281.011 kW in the network's losses. Table II provides a comparison of the network. Figure.11 shows the results of a comparison between the voltage profiles of 135 bus RDS and the suggested optimisation strategies. The true power losses of many methods are shown in Figure. 12

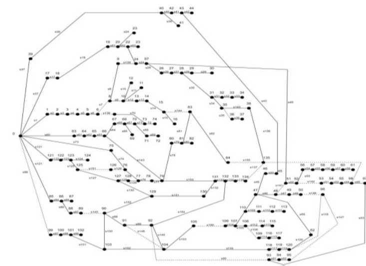

Fig.10 PSO-based network redesign for 135 buses.

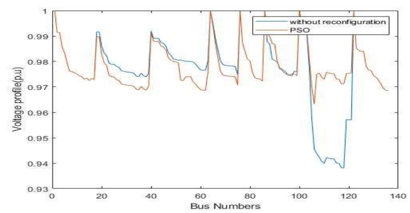

Fig.11 The PSO-reorganized voltage diagram of a 135-bus network.

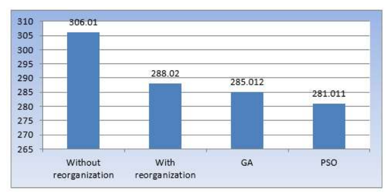

Fig.12 Impact of algorithmic watt losses

In Table II, we can see the results of an optimisation study comparing 135 different parameters in bus networks.

Table II. Optimisation methods are used to compare 135 different bus network characteristics.

Content	Without reorganization	With reorganization	GA	PSO
Switches open	136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156	141,146, 116, 150, 34, 94, 144, 138, 139, 137, 154, 152, 155, 149,148, 145, 153, 143, 147, 151, 128	141 146 116 150 34 94 144 138 139 137 154 152 155 149 148 145 153 143 147 152 126	7 35 51 90 96 106 118 126 135 137 138 141 142 144 145 146 147 148 150 151 155
Losses (kW)	306.010	288.02	285.102	281.011
%Reduction of losses	---		06.83	08.16
Minimum voltage(p.u)	0.938	0.935	0.950	0.952

V. CONCLUSION

Optimisation algorithms like GA and PSO are used to find the most efficient routes for buses 119 and 135. Both a network of 33 buses and a network of 69 buses have five dimensions, which is typical in optimisation algorithms. When the 119 and 135 bus networks are reorganised using PSO optimisation, there are less 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 PSO 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 and load flow techniques for solving the identical distribution networks, Particle Swarm Optimization's usage for reorganisation results in significant reductions in both power losses and computing time. Reorganisation may cut losses by as much as 793 kilowatts (KW), or about 30.14%, for a network of 119 buses, and by as much as 306.01 kilowatts (KW) and 281.011 kilowatts (KW) for a network of 135 buses. The reorganised data reveals the suggested Particle Swarm Optimisation technique may use many switches simultaneously to find the optimal solution.

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