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Loss Minimization by Reconfiguration in Radial Distribution Network using Whale Optimization Technique

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Abstract*: *This paper provides a new approach for solving the problem of network reconfiguration in the presence of Whale Optimization Algorithm (WOA). It is aimed at reducing actual power loss and enlightening the voltage profile in the supply system. The voltage and branch current capacity constraints have been included in the objective function evaluation. The method has been evaluated at three separate heuristic algorithms on 33-bus radial distribution systems to demonstrate the performance and effectiveness of the proposed method. In this paper the comparison of performance of two latest optimization techniques such as Whale Optimization Algorithm (WOA) with classic optimization techniques such as Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). The new optimization technique produces better result compare to other two optimization logarithm..

***Keywords* : Whale Optimization, Particle Optimization, Genetic Algorithm, Distribution System.**

I. INTRODUCTION

Power system is the combination generation, transmission and distribution. Distribution system is the tail end which is supplying the electrical power to the consumers. The demand of electricity is raising day-to-day. The increasing of electrical demand is due to increase of population and the people customizing their needs towards the luxuries. To meet with the increasing load with existing resources is more complicated issue. By the increasing usage of conventional sources like coal and crude oil the pollution extend also increasing day to day. The contribution of the losses from generation to transmission and transmission to distribution are also more. The impact of reduction of the losses at the mentioned systems are also reduced the usage of conventional fuels. By optimal placing of compensating devices at the transmission and distribution system will meet the goal of reducing the losses to great extent. But the erection and maintenance cost of compensating devices are also so complex. Mew E. Baran and Felix F. Wu [1] introduced the concept of reconfiguration of distribution system at their paper on 1989. They introduced the terminology of tie switches to change the structure of the radial distribution system for maintaining the load balancing throughout the system. M. M. A. Salama, A. Y. Chikhani [2] proposed an approach of VAR control to trouble shoot the radial distribution system problem. The VAr control at every branch can control the reactive power flow which will impact the node voltages. T. P. Wagner, A.Y. Chikhani and R. Hackam [3] proposes the application of distribution automation for feeder reconfiguration. The feeder reconfiguration will reduce the power losses with distribution automation that will improve the voltage profile of the system. T. H. Chen et al [4] proposed a novel approach distribution load flow studies which is very rigid to analyze both balanced and unbalanced systems. S. Ghosh and K. S. Sherpa [5] detailed a new approach of load flow for analyzing the losses in system. The method is successfully implemented to both balanced and unbalanced radial nature. Ola Badran et al [6] detailed a complete review reconfiguration of distribution system along with distributed generators. The optimal location distributed generators along with reconfiguration of distribution systems will make the system more reliable with lesser losses. Dong-Li Duan et al [7] proposed a methodology a enhanced genetic algorithm for reconfiguring of distribution system. They detailed the remarkable changes in classical genetic algorithm called enhanced genetic algorithm and adopted to one of the power system problems. A venkata sudhakar Reddy et al [8] proposed the method of reconfiguration system with PSO. But in this paper the load balancing was not maintained properly and losses are not reduced great percentage. M. Damodar Reddyet al [9] published the paper on reconfiguration on distribution system by using grey wolf algorithm. The paper covers the adaptation of reconfiguration problem to the latest optimization technique. But the load balancing throughout the feeder cannot achieve. The efficient optimization technique called whale optimization technique is proposed by D. Prakash [10] for optimal placing of capacitors in radial distribution networks. The paper is divided in to four sections in second section load flow is detailed and in section three reconfiguration of distribution system is discussed, in section four comparative analysis of different optimization techniques is proposed and in section five results are detailed with conclusions.

II. DISTRIBUTION OF LOAD FLOW ANALYSIS

The analysis of distribution network has been starting by determining its node voltages and distribution losses using load flow studies.

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Majority of the researchers in the literature have been strongly recommended the backward-forward sweep method for balanced radial distribution systems power flow analysis. The line currents have been calculated at backward stream using Kirchhoff's current law (KCL) and the node voltages have been calculated at forward stream using Kirchhoff's Voltage law(KVL). The equations that are used in for calculating power losses, branch currents and node voltages are shown below.

$$S_{Ln} = P_{Ln} + jQ_{Ln} = V_n I_{Ln} \qquad (1)$$

The load current at any node n is given by

$$I_{Ln} = \left[\frac{P_{Ln} + jQ_{Ln}}{V_n} \right]^* = \frac{P_{Ln} - jQ_{Ln}}{V_n^*} \qquad (2)$$

Where, $P_{L,n}$, $Q_{L,n}$ and V_n are the active power demand, reactive power demand, the voltage magnitude at load bus respectively.

A. Formation of BIBC matrix

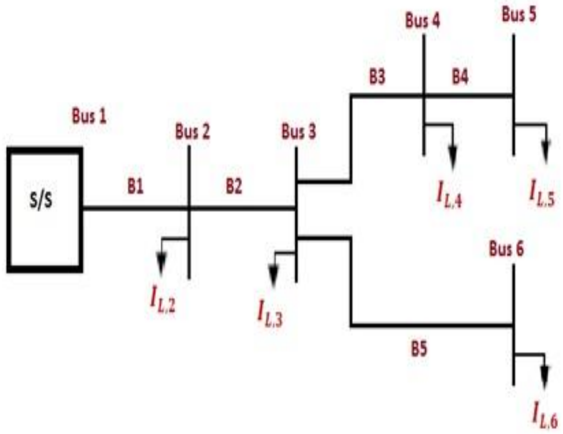

Fig. 1 A Sample 6-node radial distribution system.

The current equations can be found by using KCL for Fig 1 is given as

$$I_{B5} = I_{L6} \qquad (3)$$

$$I_{B4} = I_{L5} \qquad (4)$$

$$I_{B3} = I_{L4} + I_{L5} \quad (5)$$

$$I_{B2} = I_{L3} + I_{L4} + I_{L5} + I_{L6} \qquad (6)$$

$$I_{B1} = I_{L2} + I_{L3} + I_{L4} + I_{L5} + I_{L6} \quad (7)$$

Thus, the correlation among load currents & line currents in matrix structure as

$$[I_B] = [BIBC][I_L] \qquad (8)$$

The receiving side voltages can be estimated by forward sweep as

$$V_q(k) = V_p(k) - I_B(k)^* Z_B(k) \qquad (9)$$

B. Total System Real Power Losses

The total real power loss in a distribution system can be conveyed as

$$P_{L,T} = \sum_{k=1}^{B} I_k^{\,2} R_k \qquad (10)$$

III. NETWORK RECONFIGURATION

It is the method of updating the radial construction of the electrical distribution arrangement to diminish the losses for better voltage profile. The no of tie switches in a supply arrangement is influenced by the no of loops, by closing tie switches. The different combination tie switches along with main branches will make the system more reliable for diminishing the losses and upgrading voltage profile. The following table I will give the no possible loops in standard 33 node radial distribution system. It is shown in fig.2

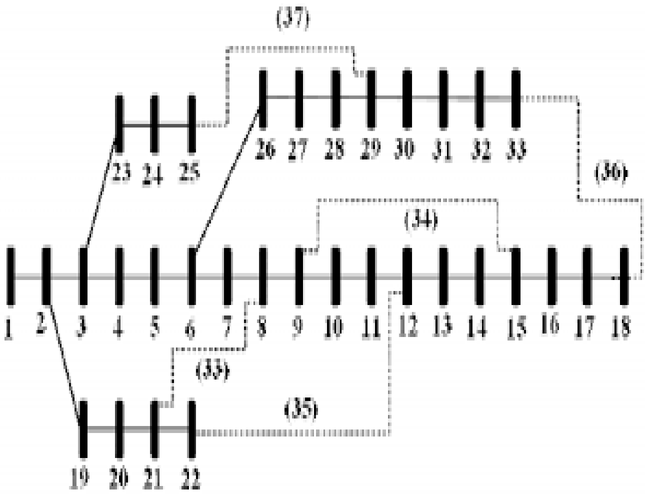

Fig 2. 33 Node radial distribution systems along with Tie line switches.

Table- I: Loops of 33 radial distribution system with five tie line switches.

Node No.	Loop1	Loop2	Loop3	Loop4	Loop5
1	3	2	8	8	9
2	4	3	9	9	10
3	5	4	15	10	11
4	6	5	16	11	12
5	26	6	17	12	13
6	27	7	18	22	14
7	28	8	33	21	15
8	29	21	32		
9	25	20	31		
10	24	19	30		
11	23		29		
12			28		
13			27		
14			26		
15			6		

The table 1 shows the loop formation with the tie line switches combination. The selection of suitable location of tie line switches will make the radial distribution system with load balancing. Since all the nodes are not loaded with constant. So the selection of suitable location of tie line switches is more important.

The selection of tie line switches for small radial distribution system might be lesser complex but for practical radial distribution systems which are higher nodes, selection of tie line switches is huge task. By the adoption this power system problem to the heuristic optimization techniques the selection of the tie line switches might become very easy. The further sections will give a detailed explanation, on adoption of reconfiguration problem to the heuristic algorithms like GA, PSO, BWO.

IV. NETWORK RECONFIGURATION USING GENETIC ALGORITHM (GA)

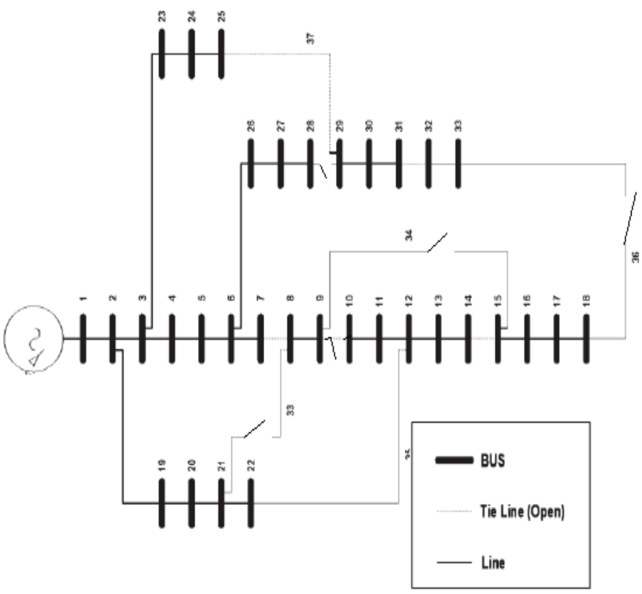

Fig 3. Reconfiguration of 33 radial distribution system with GA.

Genetic algorithm is classical optimization heuristic algorithm which is adopted to all the disciplines for optimizing their disciplinary parameters for fruitful results. The introduction about the GA is not needed in this scenario. The way how to adopt the GA parameters to the reconfiguration parameters is important as per electrical engineer point of view. The important parameters of GA for solving reconfiguration problem are shown in table II. The algorithms and flowchart for the reconfiguration problem for reducing the losses is discussed in following section. Since it is the classical heuristic algorithm, so the researchers thought that the reduction of losses and improvement of voltage profile are great extent. By comparing with updated heuristic optimization techniques the researchers came to know further improvement in the system to make it more feasible.

Table- II Parameter values of GA

Sl.no	Name of the Parameter	Value
1	Population	50
2	Generations	100
3	Mutation	0.7
4	Crossover	0.65

V. ALGORITHM FOR RECONFIGURATION GENETIC ALGORITHM USING GA

1) The branch numbers of distribution system generate with random function with the number of chromosomes in initializations.

2) The Fitness which is losses of the needed distribution system is calculated by using load flow analysis for each set of tie switches.

3) Store all the results until all the population are considered for calculating the fitness value

4) (a) Considering two chromosomes, c1 and c2, from the origin population using appropriate Objective feature selection.

(b)To acquire a child chromosome, apply one-point crossover to c1 and c2 with crossover frequency pc.

(c)Apply uniform mutation to c with mutation rate pm to generate c′.

(d)Attach c′ to the population of the successor.

5) Swap the population of source with the population of the successor.

6) Repeat from step 2 until stopping criteria meets.

By applying the above algorithm to minimize the losses and improving the voltage profile. The combination of the switches, minimum voltage of the distribution system and percentage of loss minimization are given in table II. The comparative voltage profile of the distribution system along with different optimization techniques with reconfiguration is shown in the fig 3.

VI. NETWORK RECONFIGURATION USING PARTICLE SWARM OPTIMIZATION (PSO)

The particle positions are illustrative as local best and global best. PSO has been successfully implemented to many disciplines for optimizing their problem. This is faster and accurate when compared with Genetic algorithm (GA), Simulated Annealing (SA) etc., to get the better solution the swarm fly searched in multidimensional approach. By adjusting particle position in the search space with the flying experience of its own has been at updated time.

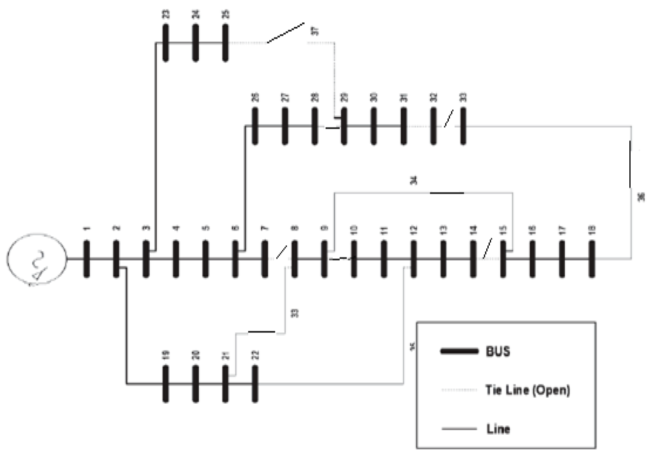

Fig 4. Reconfiguration of 33 radial distribution systems with PSO

The following equations will define the needed terminilogy of the PSO for reconfiguration of the power system.

$X_i=(x_{i1},x_{i2},\ldots x_{id},\ldots x_{iD},)$ (10)

Every particle defends a memory of its earlier best location which is characterized as:

$P_i=(p_{i1},p_{i2},\ldots p_{id}..p_{iD,})$ (11)

The preeminent one amid all the particles in the population is characterized as:

$Pg=(Pg1,Pg2..Pgd\ldots Pg_{D},)$ (12)

The velocity ofevery particle is considered as:

$V_i=(v_{i1},v_{i2},\ldots v_{id}\ldots v_{iD},)$ (13)

The maximum velocity is represented as:

$V_{max}=(v_{max1},v_{max2},..v_{maxd}\ldots v_{maxD})$ (14)

The velocity V_i of every particle is clamp to a maximum velocity V_{max} which is precised by the user. V_{max} find out the resolution with which regions between the current position and the objective position are seeded. Hefty values of V_{max} help global investigation, while slighter values support local utilization. If V_{max} is too small, the swarm may not discover adequately further than locally fine regions. On the further hand, too bulky values of V_{max} peril the leeway of mislaid a superior region. At every iteration a new velocity value for every particle is estimated according to its current velocity, the distance from the global best position. The updated velocity value is then utilized to evaluated the next position of the particle in the explore space. This procedure is then iterated a number of times or until a minimum error is achieved.

VII. STEP BY STEP PROCEDURE FOR PSO FOR RECONFIGURATION OF DISTRIBUTION SYSTEM:

Reconfiguration of radial distribution system with PSO , the following steps are to be followed:

Number of variables = number of dimensions

Step1: Randomly initialize the position and velocity of each particle in the swarm within their

Respective limits.

Step2: If iteration is equal to maximum iteration, then stop else go to next step.

Step3: P_{best} is set to all particles and G_{best} is selected among the P_{bests}.

Step4: For all particles, run load flow considering one particle at a time and calculate the fitness.

Step5: Is the fitness of the current position of a particle is better than that of the previous position, then Pbest is set to current position otherwise P_{best} is the previous P_{best} itself. G_{best} is the best among the P_{bests}

Step6: Update the velocity and position of each particle according to equations

$$V_i^{k+1} = W * V_i^k + C_1 * rand_1 * \left(P_{besti} - S^k{}_i\right) + C_2 * rand_2 * \left(G_{besit} - S_i^k\right) \quad (15)$$

$$S_i^{k+1} = S_i^k + V_i^{k+1} \quad (16)$$

V_i^k =Velocity of agent i at K^{th} iteration

V_i^{k+1} = Velocity of agent i at $(K+1)^{th}$ iteration

S_i^{k+1} =Current position of agent i at $(K+1)^{th}$ iteration

S_i^k =Current position of agent i at k^{th} iteration

$C_1=C_2$=individual and social acceleration constants (0 to 3)

W=The inertia weight

$P_{best\,i}$ = Particle best of agent i

G_{besit} =Global best of the group

Step7: Check if the position and velocity are feasible, if not then re- randomize the position and velocity within the limits.

Step8: If the maximum iteration is reached stop otherwise go to step 2.

By applying the above algorithm to minimize the losses and improving the voltage profile. The combination of the switches , minimum voltage of the distribution system and percentage of loss minimization. Ate given in table III. The comparative voltage profile of the distribution system along with different optimization techniques with reconfiguration is shown in the fig 4.

Table III Parameter values of PSO

Sl.no	Name of the Parameter	Value
1	Particles	50
2	Maximum iterations	100
3	Mutation	0.7
4	Crossover	0.65

VIII. NETWORK RECONFIGURATION USING WHALE OPTIMIZATION(WO):

Whale optimization algorithm is proposed by seyedal mirjali. It is a latest optimization which is inspired by the behavior whale searching for its food. This algorithm has three operators to simulate the search for prey , encircling prey and bubble.net foraging behavior of humpback whales.

Mathematical Modeling WAO:

There are three methods of searching for its food which is called prey. The method of hunting the food I,e small fish is called bubble –net hunting. At first the whale encircling to the prey by releasing the bubbles if the prey is of huge size then the no of bubbles releasing form other end are going to lesser. Then the whale at the other end decides the distance of the prey. This can be mathematically modeled by the equations.

$D=|C.X^*(t)- X(t)|$ (17)

$X(t+1)=X^*(t)-A.D$ (18)

Where

t is current iteration

A and C are coefficient vectors

X^* is the position vector of the best solution

X is position vector

The A and C are determined

$A=2a.r-a$ (19)

$C=2.r$ (20)

The algorithm for the WOA is given as follows

1. Initialize the branch numbers with the size of m X n where m is the number of tie breakers and n number of whale population Xi (i = 1, 2, ..., n).
2. Objective function which is losses of the radial distribution system for every search agent.
3. Consider X^* is the best agent at search.

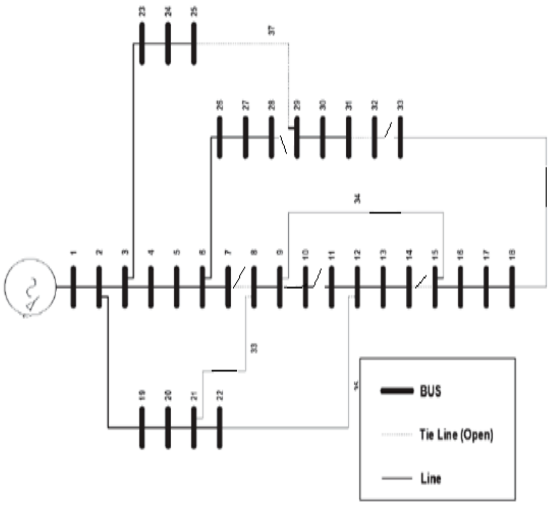

Fig 5. Reconfiguration of 33 radial distribution system with WOA

4.Start the loop with respect to maximum generations

5.With every search agent

6.Revise a, A, C, l, and p

7.Compare the value of p with 0.5,

8.Relate (|A|< 1)

9.Revise the position of the present search agent

10.Otherwise relate (|A| >=1)

11.Choose a random search agent (X_{rand})

12. Update the location of the recent search agent

13.Update the location of the existing search

14.Verify if any search agent goes beyond the search space and amend it Calculate the fitness of each search agent Update X* if there is a better solution t=t+1

15.End of the loop.

16.return X*

Table IV Parameter values of WOA

Sl.no	Name of the Parameter	Value
1	Searching Agents	50
2	Iterations	100
3	prey	0.45
4	Crossover	0.65

Here the Searching agents are initialize with the branch numbers to be open.

IX. RESULT AND CONCLUSIONS

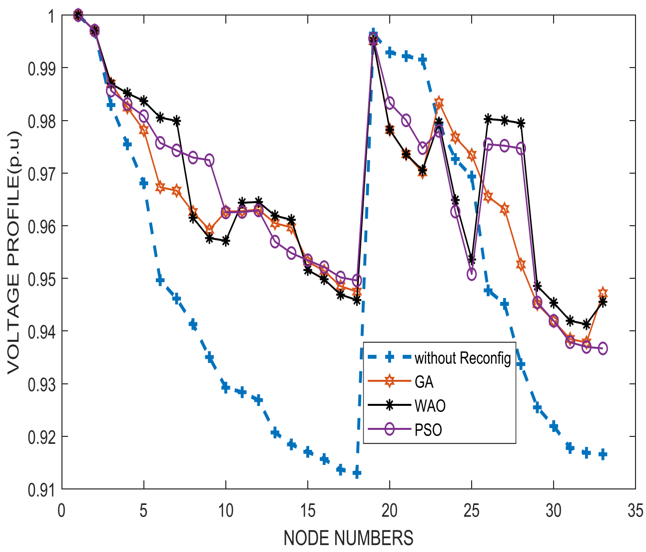

Fig 6. comparative voltage profile of Reconfiguration of Distribution system by GA, PSO and WAO

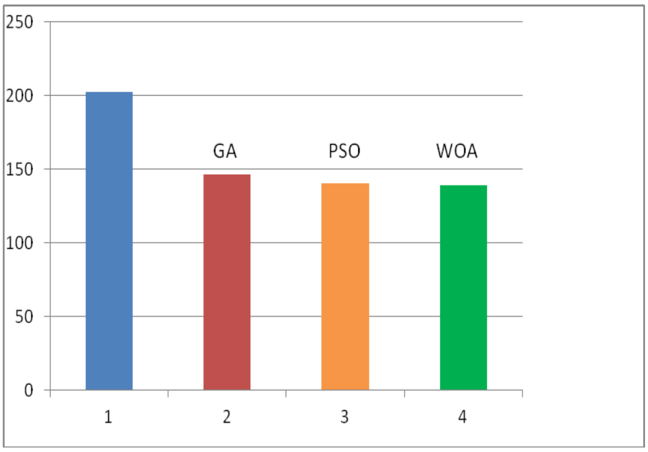

Fig 7. Comparative analysis of reduction of looses by GA,PSO andWAO

Table V Comparative analysis of loss reduction of reconfiguration of distribution system by GA, PSO and WAO

Method of Reconfiguration	Without reconfiguration	GA	PSO	WOA
Switches open	33, 34, 35, 36, 37	33, 9, 34 ,28, 36	7, 4, 10, 32 28	7, 9, 14, 32, 37
Losses	202.39 kW	146.39 Kw	140.71 Kw	139.55 kW
% reduction of losses	---	27.67	30.48	31.05
Minimum Voltage	0.913 p.u	0.936 p.u	0.938 p.u	0.946 p.u

The heuristic algorithms which are proposed in the earlier are applied to the 33 node distribution system. From the above table 6 the whale optimization technique gave lesser losses, which make good load balancing. The WAO reduce the losses by 31.05%.

The same technique will be further use for placement of distributed generators along with capacitor with and without reconfiguration of power systems.

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