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Optimal Reconfiguration of Electrical Distribution System by Whale Optimization Algorithm

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Abstract: The prime motto of the electrical power system is to provide the good and high quality power to the consumers. As the life in the society is expanding hugely, hence the need of the electrical power is additionally expanding suggestively. In this manner expanding the power generation as well as beating the significant issues in the electrical distribution system has turned into a test. The strange conditions can't be normal however when happened; the recuperation ought to be made as quickly as time permits. In this work, a modern artificial intelligence based algorithm is implemented for the reconfiguration of an electrical radial distribution network. This algorithm helps to bring down the active power loss and intensify the voltage profile of the network. This paper has proposed a nature-based guided metaheuristic Whale Optimization Algorithm (WOA). WOA is motivated by the smart foraging approach of the humpback whales. To ratify the efficiency of the proposed approach, WOA is successfully simulated on IEEE standard 69 bus and 119 bus system.

Keywords: Artificial intelligence, Metaheuristic, Whale Optimization Algorithm, Reconfiguration, Active Power Loss, Voltage Profile.

I. INTRODUCTION

This ever changing world always demands more and more, so it's true in the case of electrical distribution systems. The electrical distribution system is being extended too far and becomes larger and complex so that it can meet the increasing load demand. It affects the system adversely in terms of power loss and low voltage regulation. To sort out these problems, a suitable and sustainable operation of the system is needed. The most commonly loads of a distribution system consists of a industrial, private enterprise, urban and agricultural loads. The real power loss makes the system less efficient and is a major concern. According to the data [1], the generated power loss in a distribution network is 13%.Therefore, to sort out these problems of distribution network , the reconfiguration methodology is opted in this work. Network reconfiguration is a technical way of alternating the topological architecture of the system with the assistance of switching the position (open/close) of sectionalising and tie switches.

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Switching helps us to obtain the optimal combination of switches, which reduces the line losses. It fulfils wide objectives such as the service restoration to dark areas, curtailment real power loss, and load stabilization with feeders. So with the help of reconfiguration, an existing system can be transformed into a more reliable, secure, and stable condition. In past decades many research work have been performed in the sector of reconfiguration.

In an artificial neural network [2] based approach, the back propagation algorithm is used for the loss minimization. This method provides a quick result as it avoids the complex calculation throughout the course of searching process. To achieve the global solution, a modified tabu search [3] algorithm is helpful. It is a deterministic algorithm which avoids local minimum. A radiation distribution network load flow (RDNLF) method is implemented in a refined genetic algorithm [4]. Few changes from GA has been done for this algorithm like a coding chromosome, fitness function and mutation arrangement. The minimization of the investment capital of the power loss is done by the heuristic based approach. Simulated annealing [5] is opted, as it require less time to provide accurate output. An evolutionary based technique MBFOA [6] can converse easily. This algorithm is having the advantage that it can be applied to a larger system and capable of providing the accurate solution. The alteration of switches balances the load, and thus brings down the real power loss. Based on the switching technique the artificial bee colony algorithm [7] work effectively in loss reduction and maintains the system low voltage profile. Research has also focused on the area Improvement in global search and maximizing the result of local solutions. An improved tabu search (ITS) algorithm [8] is efficiently implemented for global search problems.

II. PROPOSED METHOD

WOA is a new metaheuristic optimization algorithm. It has been recognized by S. Mirjalili [9]. WOA follows the uncommon hunting behaviour of humpback whales. This foraging mechanism is executed by releasing a bubble trap in a typical inverted conical shape around the prey. The WOA is categorised and mathematically modelled as:

- Enclose the prey
- bubble net hunting approach
- search the target

A. Enclose The Prey

In this process, firstly the whale identifies the target site of prey and finally encircles them. This behaviour is mathematically modelled as:

$$\vec{X}(t+1) = \overrightarrow{X^*}(t) - \vec{A} - \vec{D} \quad (1)$$

$$\vec{D} = \left|\vec{C}\cdot\overrightarrow{X^*}(t) - \vec{X}(t)\right| \quad (2)$$

$$\vec{A} = 2\cdot\vec{a}\cdot\vec{r} - \vec{a} \quad (3)$$

$$\vec{C} = 2\cdot\vec{r} \quad (4)$$

Where $\vec{X}$ is the position vector, $\vec{X}^*$is optimallybest obtained position vector among others. '**t**' is the ongoing iteration. $\vec{\mathbf{A}}$,$\vec{\mathbf{C}}$ are coefficients of vector. In the course of iteration,$\overrightarrow{\boldsymbol{a}}$ is dropped linearly from 2 to 0. The range of random vector $\vec{\boldsymbol{r}}$ is [0,1].

B. Bubble-Net Hunting Approach

The statistical modelling of bubble-net behaviour consists of:

i) Shrinking Encircling Mechanism

The mechanism is attained by numerically mitigating the value of $\overrightarrow{a}$ in the Eq.(3). $\vec{A}$ is the arbitrary value of the range [-a,a]. The search zone $\mathbf{0 \le A \le 1}$ helps the whale to switch their position from X,Y to X*, Y*as shown in fig.1.

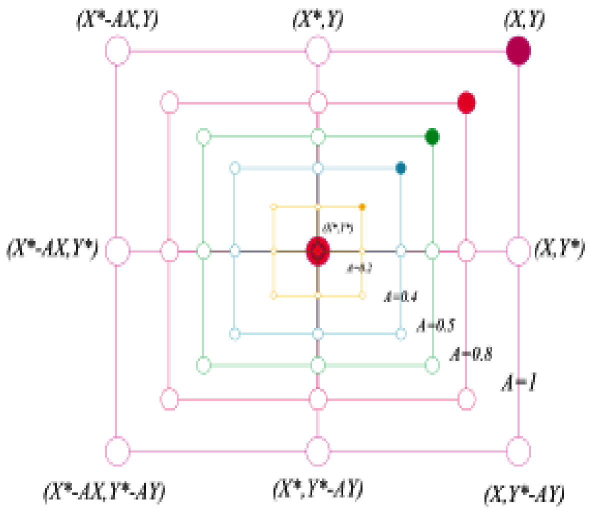

Fig.1: Shrinking encircling pattern

ii) Spiral Updating

This procedure is based on the fact that the both the location of prey(X^*, Y^*) and whale (X, Y) is already known as shown in Fig.2.This behaviour mathematically modelled as:

$$\vec{X}(t+1) = \vec{D'}\cdot e^{bl}\cdot\cos(2\pi l) + \overrightarrow{X^*}(t) \quad (5)$$

Where $\vec{D'} = \left|\overrightarrow{X^*}(t) - \vec{X}(t)\right|$ the space between the whale and prey 'b' is the constant for defining the logarithmic gyrate structure, and 'l' refers to an arbitrary value in the range [−1, 1]. Whales used to hunt the prey either in spiral manner or in a shrinking loop manner. That is why there is 50% likelihood to go for either spiral-shaped or shrinking encircling behaviour. Mathematically is can be represented as:

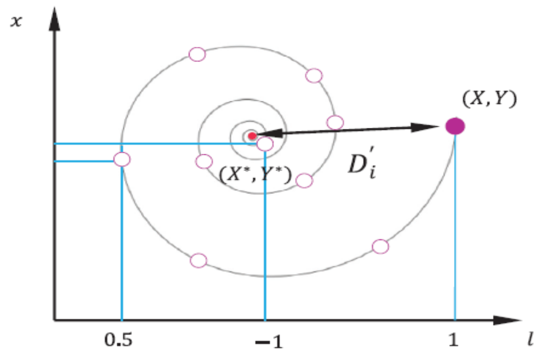

Fig.2. bubble net Spiral behaviour

$$\vec{X}(t+1) = \begin{cases} \overrightarrow{X^*}(t) - \vec{A}\cdot\vec{D} & \text{if } p < 0.5 \\ \vec{D'}\cdot e^{bl}\cdot\cos(2\pi l) + \overrightarrow{X^*}(t) & \text{if } p > 0.5 \end{cases} \quad (6)$$

Where "p" refers to the arbitrary value in [0, 1]

C. Search the target

This search process is based on the randomly hunting the prey location. By varying the $\vec{\mathbf{A}}$vector, the global search process being taken into consideration.$|\vec{\mathbf{A}}| > \mathbf{1}$ implies exploration which allows WOA for the global search. Mathematically the behaviour can be expressed by:

$$\vec{D} = \left|\vec{C}\cdot\vec{X}_{rand} - \vec{X}\right| \quad (7)$$

$$\vec{X}(t+1) = \vec{X}_{rand} - \vec{A}\cdot\vec{D} \quad (8)$$

Where $\overrightarrow{\boldsymbol{X}_{rand}}$ indicates the arbitrary location of whale in the current iteration. The flow chart of WOA is shown in fig.3. The complete step by step sequence of the WOA can be understood in a easier way with the help of flow chart.

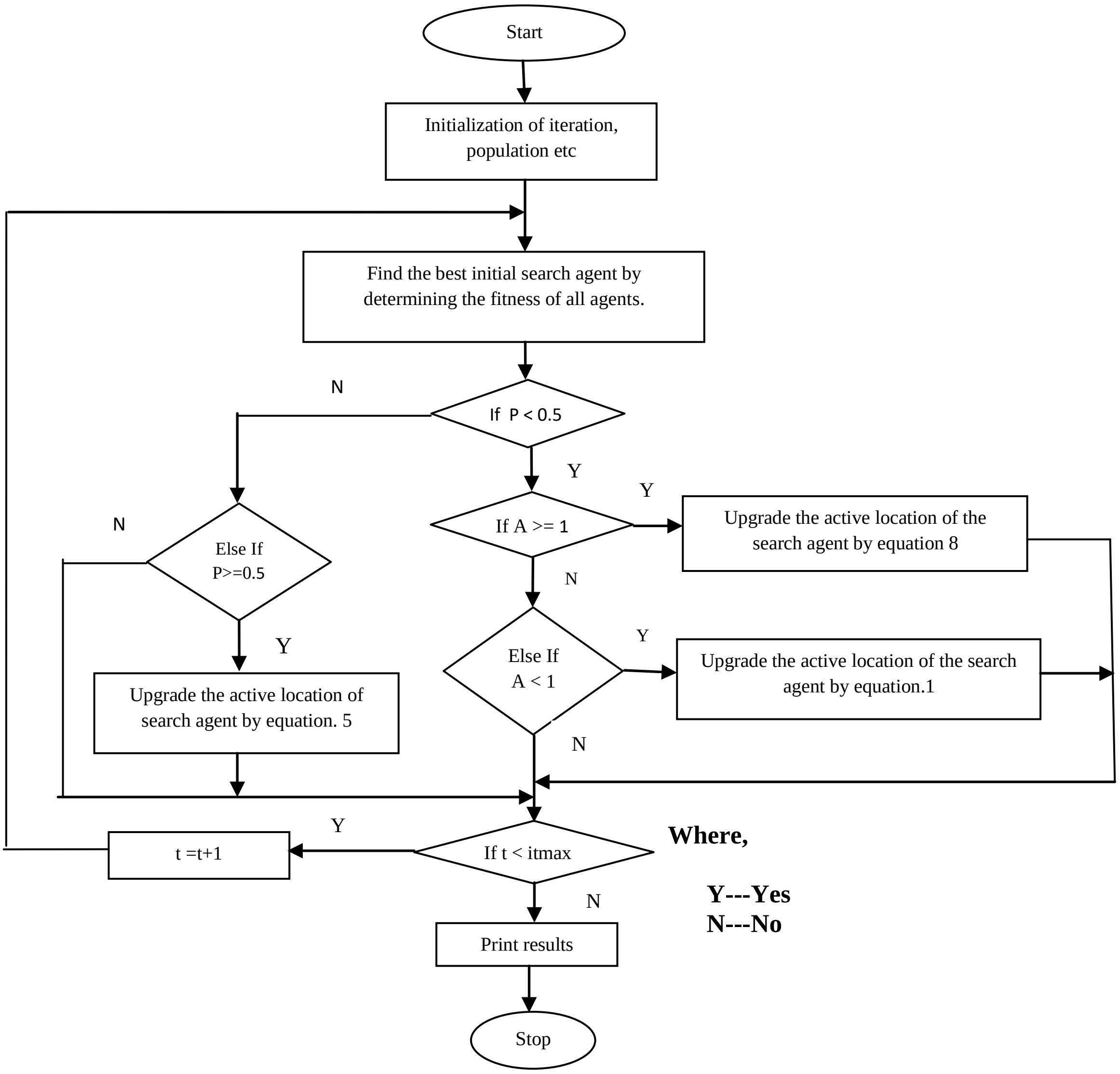

Fig. 3: Proposed WOA flow Chart

III. POWER FLOW EQUATION

The reconfiguration of is basically performed by the switching of the sectionalising and tie switches. While performing reconfiguration the main focus is done to choose the optimally best combination of the switches (sectionalising and tie switches). It helps to obtain maximum loss reduction for the network. The determination of the loss reduction before and after reconfiguration can be easily achieved by the load flow study. Consider the one line diagram of a radial system as shown in fig.4 which is taken from Hong-Chan Chang [10].

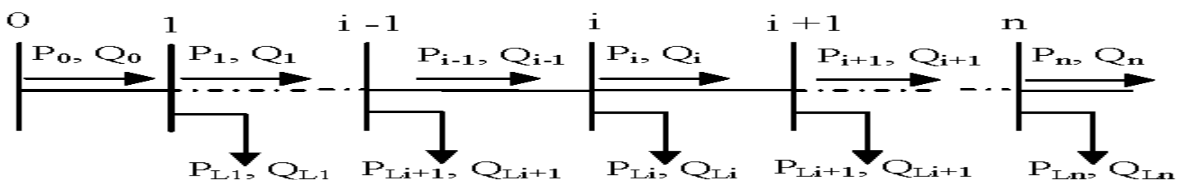

Fig.4: One-line diagram of a radial system

The power flow equation is calculated by:-

$$P_i = P_{i+1} + P_{Li+1} + r_i \frac{P_i^2+Q_i^2}{|V_i|^2} \quad (9)$$

$$Q_i = Q_{i+1} + Q_{Li+1} + x_i \frac{P_i^2+Q_i^2}{|V_i|^2} \quad (10)$$

$$|V_i|^2 = |V_{i+1}|^2 + 2(r_i P_i + x_i Q_i) - (r_i^2 + x_i^2)\frac{P_i^2+Q_i^2}{|V_i|^2} \quad (11)$$

where $\boldsymbol{P_i}$ and $\boldsymbol{Q_i}$ indicates the active and reactive power of the source end bus i, $\boldsymbol{P_{Li}}$ and $\boldsymbol{Q_{Li}}$ is the real and reactive load power for bus i, $\boldsymbol{V_i}$is bus i voltage, $\boldsymbol{r_i}$ *and* $\boldsymbol{x_i}$ is the resistance and reactance.$|\boldsymbol{V_{i+1}}|$ represents voltage magnitude at $\boldsymbol{i+1^{th}}$ bus.

IV. PROBLEM FORMULATION

The formulation is done in such a way that it can lessen the active power loss and to maintain a healthy profile of the system voltage. This can be achieved by optimally selecting the location and the combination of the switches.

$$MinPower_{losses} = \sum_{i=1}^{n} (I_i^2)R_i \quad (12)$$

Where N is the total branch number, I_i indicates branch current at i^{th} node, and R_i is the i^{th} branch resistance.
The limitations of the network are:

1. voltage limit

$$V_{min} \le V_{bus} \le V_{max} \quad (13)$$

2. Power flow limit

The line power flow (PF_l) should be always less than the maximum limit of power flow (PF_l^{max}) as:

$$|PF_l| < PF_l^{max} \quad (14)$$

V. TEST SYSTEM RESULTS

The better understanding and the correlation of the natural hunting behaviour of the whale with the real-time distribution system plays an important role. The prey location indicates the weak bus in a given test system. The best defined agent refers to the optimally opted switch combination. Further, the update of their location is done as per the best search agent, which correlates the distribution system as the update for the selected switch combination for the operation to be performed.

A. 69-Bus System

The one line diagram of the 69-bus configuration is shown in fig 5. It comprises of 69 buses,5 tie and 68 sectionalizing switches. The net load of the network is 3801.89 kW and 2694.1 kVar. The opted base power and base voltage for a power flow study are 100 MVA and 12.66 kV respectively. The suggested method is simulated on the 69-bus network and the obtained values are shown in Table I.

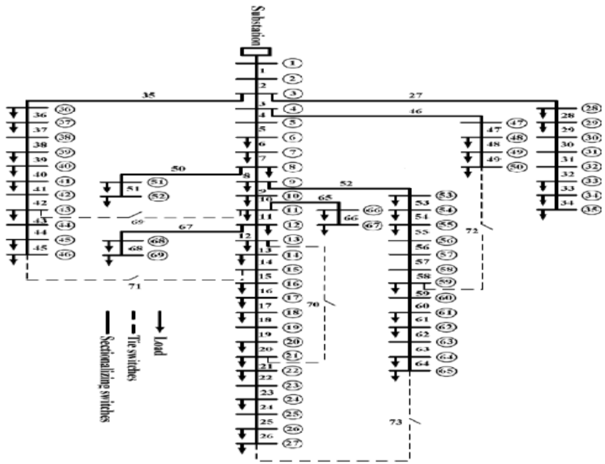

Fig 5: IEEE 69 Bus Network

The best combination of the switches for the real power loss reduction is shown in table 1.

Table-I: Results Validation of 69 bus network

Method	Tie Switch	Real Power loss (kW)	Loss reduction (%)
BFOA	18,43, 56, 61, 69	98.56	56.11
Proposed method (WOA)	14, 52, 46, 69,71	21.5162	90.41

The simulation result of the reconfiguration is compared with the existing bacterial foraging optimization algorithm (BFOA) and hence WOA is found to be effective. The fig.6 shows the result of variation of the voltage magnitude before and after the reconfiguration.

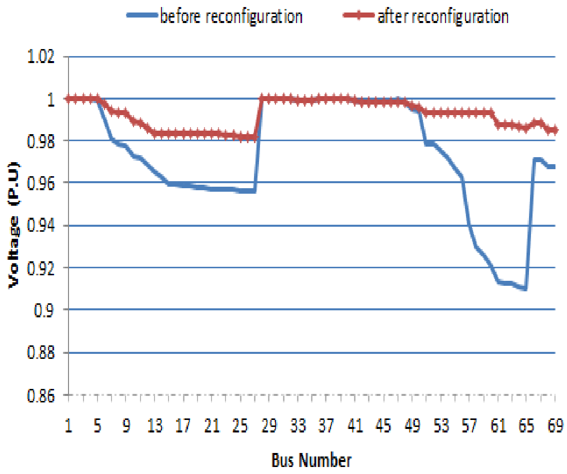

Fig 6: Voltage comparison before and after reconfiguration

A comparison of the variations of the real power loss for the different buses of the system is shown in fig.7

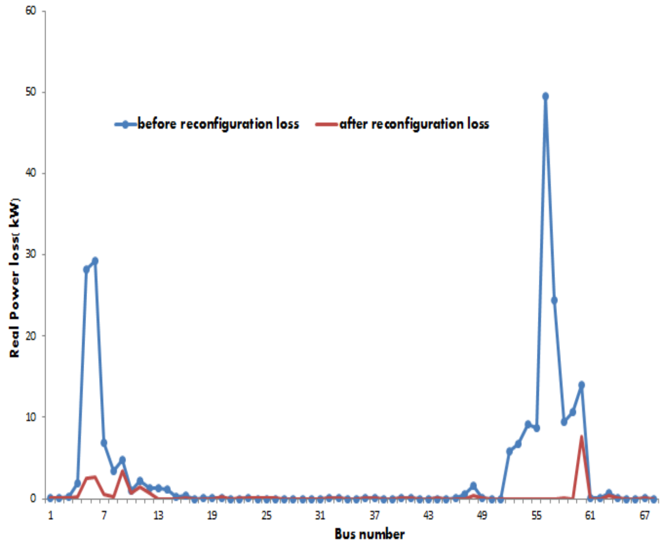

Fig:7: Real power loss comparison

B. IEEE 119 Test Bus System

To support the proposed algorithm efficiency, the complex model of standard IEEE 119 test system is considered. It comprises of 118 sectionalism switches (1-118) and 15 tie switches (119-133). The base voltage is considered as 11 kV and the base MVA value has opted 275 MVA. The IEEE 119 system is shown in fig.8.

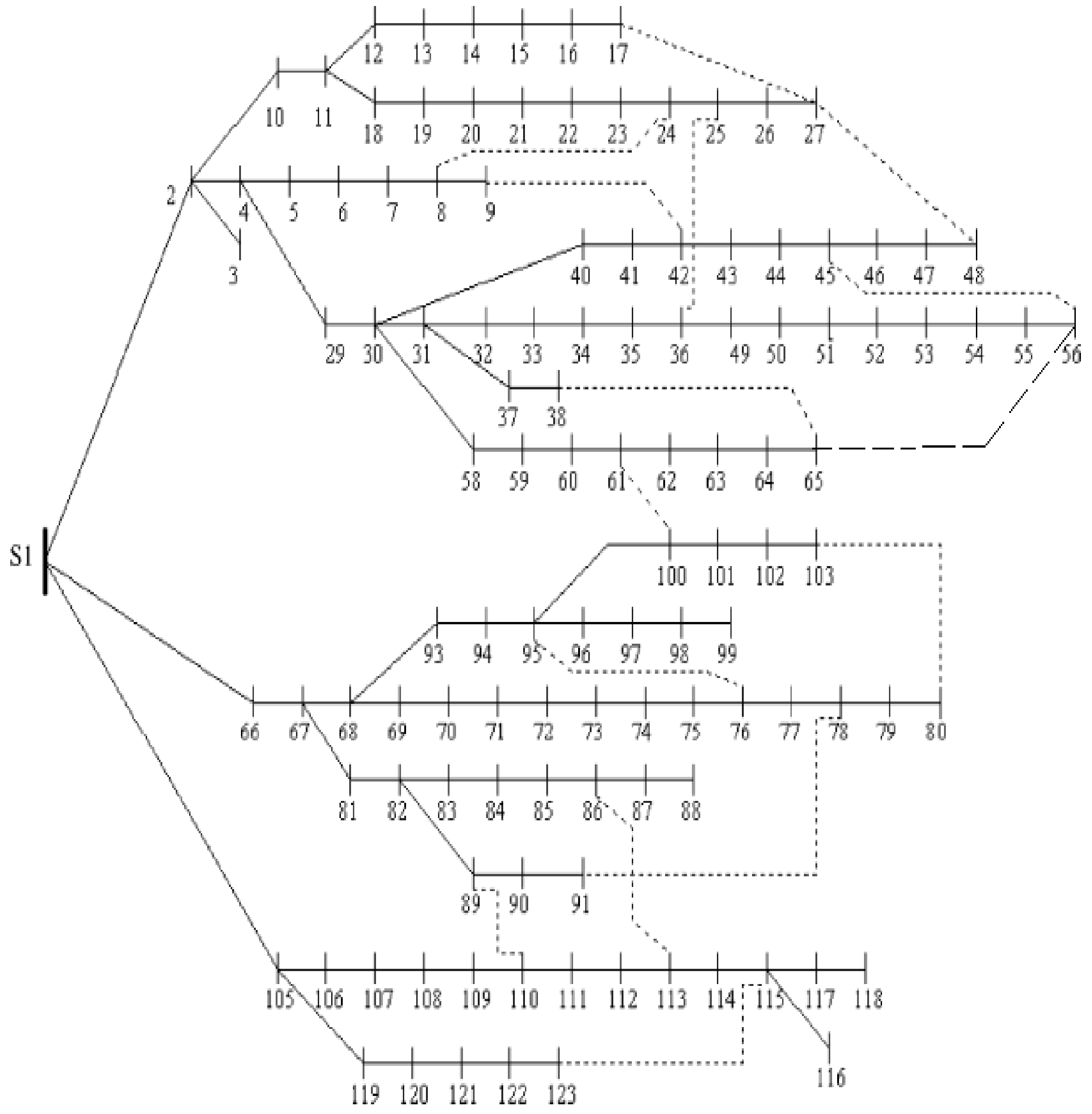

Fig 8:- IEEE 119 test bus system

Table-II: Results Validation of 119 bus network

Method	Improved Tabu Search (ITS)	Proposed (WOA)
Tie Switch	S45-44,S27-26,S23-24,S54-53,S65-51,S61-62,S41-42,S95-100,S77-78,S74-75,S101-102,S86-113,S89-110,S114-115,S35-36	S8-24,S9-42,S11-12, S25-36,S36-49,S38-65,S41-42,S65-56, S70-71,S76-95,S91-78,S95-100,S110-89,S113-86,S114-115
Real Power loss (kW)	865.865	364.637
(%) Loss reduction	33.21	71.87

For this complex system, the optimal switch reconfiguration values are tabulated in Table II. The variation of voltage magnitude is shown in fig.9

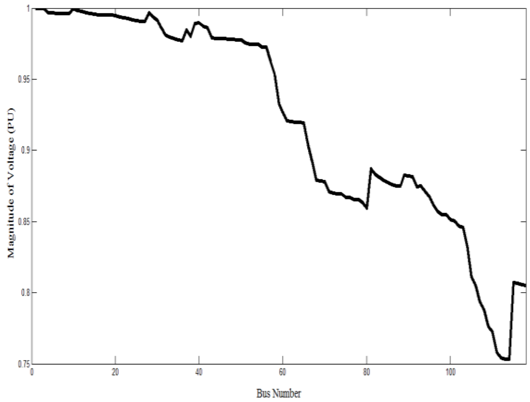

Fig 9:- Output voltage variation

The variations of real power loss of the network is shown in fig.10

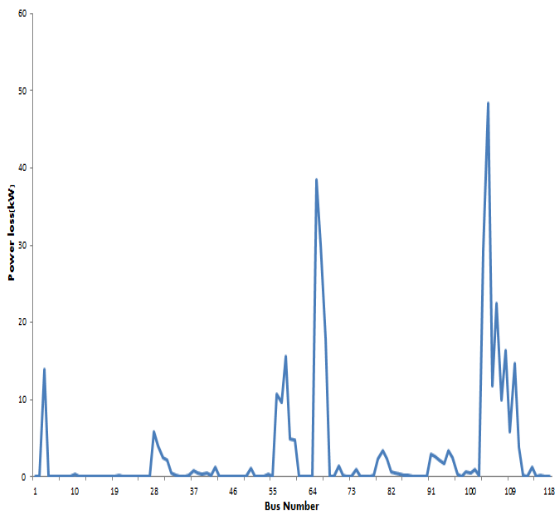

Fig 10:- variation of real power loss

VI. RESULT DISCUSSION

From the listed results of the IEEE 69 and IEEE 118 system, it can be said that the applied method WOA is effective. For the mitigation of loss and voltage improvement, the optimal reconfigured switch combination of IEEE 69 test bus system are **S14, S52, S46, S69, S71**. Before reconfiguration the network the real power loss was 224.572 kW. After successful reconfiguration, the power loss of the system becomes 21.51 kW. Therefore the loss reduction of the network is 90.41 % as shown in fig7. Apart from loss reduction, there is a remarkable enhancement in the voltage magnitude of the system, which makes the system more efficient and reliable. The voltage profile of IEEE 69 bus system is shown in fig.6. For IEEE 119 test bus system the opted optimal switch combinations are **S8-24, S9-42, S11-12, S25-36, S36-49, S38-65, S41-42, S65-56, S70-71, S76-95, S91-78, S95-100, S110-89,S113-86,S114-115**.Before reconfiguration the real power loss of the system is 1296.5 kW. After successful reconfiguration, the loss of the system becomes 364.63 kW. So, the loss reduction after reconfiguration is 71.87 %.

VII. CONCLUSION

In this paper, the prime objective is real power loss minimization in popular electrical distribution system through Whale Optimization Algorithm. The proposed algorithm is applied and tested to minimize I^2R loss minimization on IEEE 69 and IEEE 118 bus system and losses are limited to 90.41 % in case of 69 bus system and 71.87 % for 118 bus system. The results are approved with other strategies and the proposed algorithm is found to be more effective with validation of results. Hence, the suggested technique can be implemented for a large electrical distribution networks.

REFERENCES

1. S.h lee, J.J Grainger, Optimum Placement of Fixed and Switched Capacitors on Primary Distribution Feeders, IEEE transaction 1981
2. M A Kashem , G B Jlasmon , A Mohamed and M Moghavvemi (1998)'Artificial neural network approach to network reconfiguration for loss minimization in distribution networks', Electrical Power & Energy Systems, Vol. 20, No. 4, pp. 247-258.
3. A.Y. Abdelaziz, F.M. Mohamed, S.F. Mekhamer, M.A.L. Badr(2010)'Distribution system reconfiguration using a modified Tabu Search algorithm', Electric Power Systems Research 80 943–953
4. J.Z. Zhu(2002) 'Optimal reconfiguration of electrical distribution network using the refined genetic algorithm', Elect. Power Syst. Res. 62 (1) 37– 42.
5. Victor Parada, Jacques A. Ferland, Miguel Arias, and Keith Daniels(2004) 'optimization of electrical distribution feeders using simulated annealing, ieee transactions on power delivery', VOL. 19, NO. 3.
6. S. Naveen, K. Sathish Kumar, K. Rajalakshmi,' Distribution system reconfiguration for loss minimization using modified bacterial foraging optimization algorithm', Electrical Power and Energy Systems 69 (2015) 90–97.
7. Optimization of Distribution Network Configuration for Loss Reduction Using Artificial Bee Colony Algorithm R.Srinivasa Rao, S.V.L. Narasimham, M. Ramalingaraju
8. Distribution system reconfiguration for energy loss reduction considering the variability of load and local renewable generation AboelsoodZidan*, Ehab F. El-Saadany Department of Electrical and Computer Engineering, University of Waterloo, 200 University Ave. W, Waterloo, ON N2L3G1, Canada
9. Seyedali Mirjalili,(2016) 'The Whale Optimization Algorithm', Advances in Engineering Software 95 51–67
10. Hong-Chan Chang and Cheng-ChienKuo(1994) 'Network reconfiguration in distribution systems using simulated annealing',Electric Power Systems Research, 29 227-238.

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