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Optimal tuning of Reconfiguration of Radial Distribution System using Quasi-Oppositional Moth Flame Optimization

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Abstract — Optimal reconfiguration and reliability enhancement are the most significant objectives in the radial distribution systems. Because, enhancing the performance of power systems at different distribution level requires the rearrangement of network. For this purpose, this paper employs a Quasi-oppositional Moth flame Optimization **(QOMFO)** for improving the performance of radial distribution systems. The key factors of this work are to obtain the loss minimization. Also, to check feasibility proposed method has applied on 33-bus and 69-bus radial distribution systems. In addition to that, the obtained results are compared with some other conventional optimization techniques for proving the betterment of the proposed algorithm.

Keywords — ***Radial Distribution Systems, Optimal Reconfiguration, Capacitor, Power loss minimization, 33-bus system, 69-bus system.***

1. INTRODUCTION

The main characteristic of distribution system is that different feeders radiate from the generating station and feed the distributors at one end. Although the system is simple and less expensive, it has its own drawbacks as in a fault in the feeder will result in the supply failure for the rest of the consumers.

In any kind of distribution system, reactive power compensation is a matter of interest for any electrical engineer. Efficiently managing the losses in a system i.e., minimising them is a topic of discussion. One way to minimize losses is by optimally placing and sizing energy storage systems [1]. Now optimally placing distributed generator (DG) units becomes a big question whose answer can be understood by several algorithms such as sine-cosine algorithm [2], coyote optimization algorithm [3]. Since the cost of placement, investment and operational cost is high, a need of alternatives with more efficiency and less cost effective arises. Installing capacitors and going for renewable resources becomes a matter to think upon. Installing shunt capacitors in parallel with feeders helps correct the lagging power factor in the distribution line as it can leading power factor. In regard to capacitor installation selecting optimal positions in the system cannot be avoided. Some techniques can be really helpful in placement, sitting and sizing of shunt capacitors such as atom improved search

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optimisation [4], polar bear optimization algorithm [5], flower pollination algorithm[6]. Although the main purpose of this paper is to think of ways of reconfiguration of the radial

distribution system. By reconfiguration of a system we mean to select the best configuration which gives minimum power loss. This can be achieved by the operation of opening or closing of switches to alter topological structure of distribution feeders to form a new network which reduces power loss. Several techniques have been proposed regarding reconfiguration of distributing system such as grey wolf optimizer algorithm proposed by Reddy et. al.[7], Grasshopper Optimization Algorithm [8] by Ahanch et at. and reliability enhancement method by Anteneh et al. [9].

Recent days experiences reveal that bulk of service breakdowns for the consumers occur at distribution level which ultimately makes the researchers to carefully review and find ways of developing more efficient operation stages of a power system. Reduction of loss and increasing energy efficiency with more reliable and stable systems are the factors by which optimal configuration of radial distribution systems can be obtained.

The arrangement of paper is done in following manner. Mathematical formulation is described under section 2. The Moth Flame Optimization algorithm is described under section 3. Quasi-Oppositional based learning is described under section 4. QOMFO applied to reconfiguration problem is discussed under section 5. Results and discussion are described under section 6. Conclusion is described under section 7

2. MATHEMATICAL PROBLEM FORMULATION

The problem description of distributed power system in this section by incorporating capacitor for reconfiguration.

2.1 Objective function

By literature it is tested that unbalanced deeply loaded condition sometime resulted heavy power losses in the radial network. So Real power loss is equal to

$$P_{Rloss} = \sum_{m=1}^{p}\sum_{n=1}^{p}\frac{r_{m,n}}{v_m v_n}\cos(\mu_m - \mu_n)(A_mA_n + B_mB_n) + \frac{r_{m,n}}{v_m v_n}\sin(\mu_m - \mu_n)(B_mA_n - A_mB_n) \quad (1)$$

Here , P_{Rloss} is the real power loss, r_{mn} is resistance of the branch connected between m^{th} and n^{th} node, P is the number of nodes in system , A_mB_m are net real and imaginary power of m^{th} bus. A_nB_n are net real and imaginary power of n^{th}, $\mu_m\mu_n$ are voltage angle at m^{th} and n^{th} bus.

2.2 Load modelling

Now , we considered , various kind of load. The active and reactive loads are specified below:-

$$PL(p) = PL_O(p)(s_1 + s_2|v(p)| + s_3|v(p)|^2) \quad (2)$$

$$QL(p) = QL_O(p)(t_1 + t_2|v(p)| + t_3|v(p)|^2) \quad (3)$$

Now (s_1, t_1), (s_2, t_2) and (s_3, t_3) are the arrangement of fixed power, fixed current and fixed impedance loads respectively. Here, the condition for fixed power load $s_1=t_1=1$ and $s_2=t_2=s_3=t_3=0$; condition for fixed current load $s_2=t_2=1$ and $s_1=t_1=s_3=t_3=0$ condition for fixed impedance load $s_3=t_3=1$ and $s_1=t_1=s_2=t_2=0$; condition for composite type load $s_1=t_1=0.4$, $s_2=t_2=0.3$ and $s_3=t_3=0.3$ respectively.

2.3 CONSTRAINTS

In the reconfigured radial power system the real power loss is subjected to following constraints:

2.3.1 Voltage limit: The main cause of voltage fluctuation and outage in the system is from the distribution system so, these issues can be resolved by proper designing of the distribution network. Here the voltage should be in the operating range.

$$V_m^{min} < V_m < V_m^{max} \tag{4}$$

2.3.2 Real Power Limit

The real power limit also lies in operating range of various busses must lie within the operating range. It is defined as under:-

$$P_m^{min} < P_m < P_m^{max} \tag{5}$$

2.3.3 Reactive Power Limit

Mathematical expression of reactive power limit is as given below:-

$$Q_m^{min} < Q_m < Q_m^{max} \tag{6}$$

3. MOTH FLAME OPTIMIZATION

The Moth-Flame Optimization (MFO) [21] is a novel nature inspired population base meta-heuristic optimization technique first introduced by Seyadali Mirjalili in the year 2015. The moths are elegant insects which quite similar to the butterflies. They basically have two stages over their lifetime namely the Larvae Stage and the Adult stage. This algorithm is based on the unique behaviour of the flying nature of the moths at night. Moths are considered to have a unique night-time navigation method also known as transverse mechanism.

In the above-mentioned mechanism, moths fly by sustaining a fixed angle with respect to the moon at night. Though the moon is at a very large distance away from the moths, this method ensures the moths to travel in an un-deviated line. Nevertheless, when the moths are brought in the proximity of man-made light source, they tend to follow a deadly spiral path near the man-made light source. This distinctive behaviour is useful for solving real life problems.

The MFO algorithm defines moths as candidate solutions and the position coordinates vector of the moths are defined as variables. To perform the search operation within the current search area, it defines a logarithmic spiral as given below.

$$L_s\left(m_x, f_y\right) = K_x e^{an}.\cos\left(2\pi n\right) + f_y \tag{7}$$

where, the path between the x^{th} moth and the y^{th} flame is represented by K_x and, the persistent indices for the shape of logarithmic spiral is a and n is an arbitrary number where $n \in [-1,1]$.

Now, K can be determined as,

$$K_x = \left| f_y - m_x \right| \tag{8}$$

where, m_x is the x^{th} moth , f_y is the y^{th} flame and K_x is the distance between the x^{th} moth and the y^{th} flame.

On comparison to other meta-heuristic algorithms, the MFO algorithm is seen to have greater convergence rate in its results which provides better quality solutions in very less amount of time. But after this above-mentioned process is fulfilled, there is one more concern to be thought about which is that the position refreshing of the moths with respect to various locations in the particular search space may reduce the chances of achieving the best solutions. This concern can be remedied using the below stated mathematical formulation where the number of flames is reduced with every successful iteration.

$$N_f = round\left(\alpha - \beta * \frac{\alpha - \beta}{\phi}\right) \tag{9}$$

where N_f is the flame number, α is then maximum number of flames at the present time, β is the current iteration number and ϕ is the maximum iteration number.

4. QUASI-OPPOSITIONAL BASED LEARNING

Tizhoosh [22] first introduced OBL is a Novel soft computing or intelligence-based concept to enhance various optimization techniques, in solving nonlinear optimization problems it looks to be one of the most victorious theories in computational intelligence, which intensify the searching abilities of the conventional population-based optimization techniques in solving nonlinear optimization problems. The main objective in OBL is to consider the opposite or reciprocal of a guess or an assumption thereby comparing it with the original assumption and accordingly improve the chances of finding a solution faster. The OBL algorithm starts with the initialization of initial estimate that is based on some prior information about the solution or randomly. Optimal Solution could be in any direction or at least in opposite direction. For convergence opposite set of estimates are considered, which iteratively replaces the initial estimates for better solution in the direction of optimality.

A. Opposite Number

Let, the real number be denoted by $P \in [y, z]$ and P° be its corresponding opposite number is defined real number by:

$$P^\circ = y + z - P \tag{10}$$

B. Opposite Point

Say $R = (X_1, X_2, ..., X_n)$ is a point in n-dimensional space, where $P_r \in [y_r, z_r]$, $r \in \{1, 2, ..., n\}$ .The opposite point $R^\circ = (X_1{}^\circ, X_2{}^\circ, ...X_n{}^\circ)$ is defined by its components:

$$P_r{}^\circ = y_r + z_r - P_r \tag{11}$$

C. Quasi-Opposite Number

Let P be a real number between $[y, z]$ .The quasi-opposite number P^{Qo} is defined as:

$$P^{Qo} = rand(C, \breve{P}) \tag{12}$$

Where C is given by:

$$C = \frac{y+z}{2}$$

D. Quasi-Opposite Point

Let P be a real number between $[a, b]$ .The quasi-opposite point P_r^{Qo} is defined as:

$$P_r^{Qo} = rand(C_r, \breve{P}_r) \tag{13}$$

where, $C_r = \dfrac{y_r + z_r}{2}, P_r \in [y_r, z_r];\ r = \{1, 2, 3, ..., n\}$.

5.RESULTS AND DISCUSSION

To verify the effectiveness of the proposed QOBL-MFO, author demonstrated through two examples. The researcher used standard 33-bus and 69-bus radial distribution system for reconfiguration with capacitor placement to minimize power loss. The proposed methods are implemented in MATLAB software and simulations are performed on personal computer having core i3 processor, 2.53GHz, and 3GB RAM. The proposed techniques are run for 50 population size and 100 iterations for each case and the best results are shown in the corresponding Tables.

A. 33-Bus System

Initially, to show the effectiveness of proposed QOBL-MFO, it is tested on small 33-bus distribution system consisting of 37 branches. The single line diagram of 33-bus radial distribution system is shown in Figure 1 and the line data and load data are given in [10] with rated voltage of 12.66KV. After load flow, a real power loss without capacitor at rated load is 210.998. Table 1 shows the power loss, optimal location and optimal size of capacitor before and after reconfiguration by proposed techniques. The well-known optimization technique namely QOMFO and MFO are analysed and compared the results with other well-known algorithms to verify the supremacy of the said algorithms.

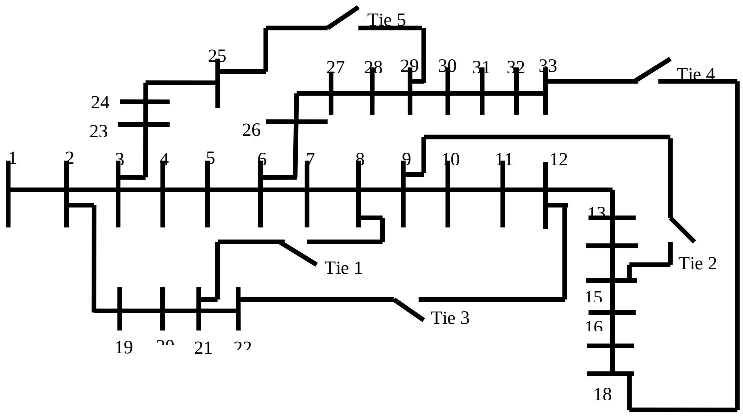


Figure 1 - Single line diagram of 33-bus radial distribution system

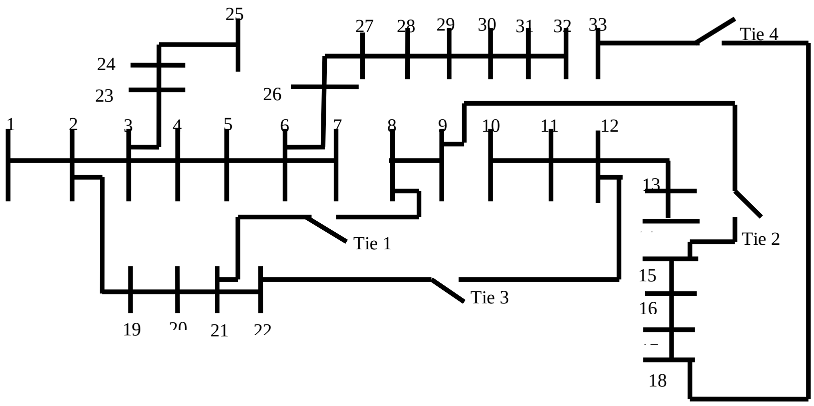
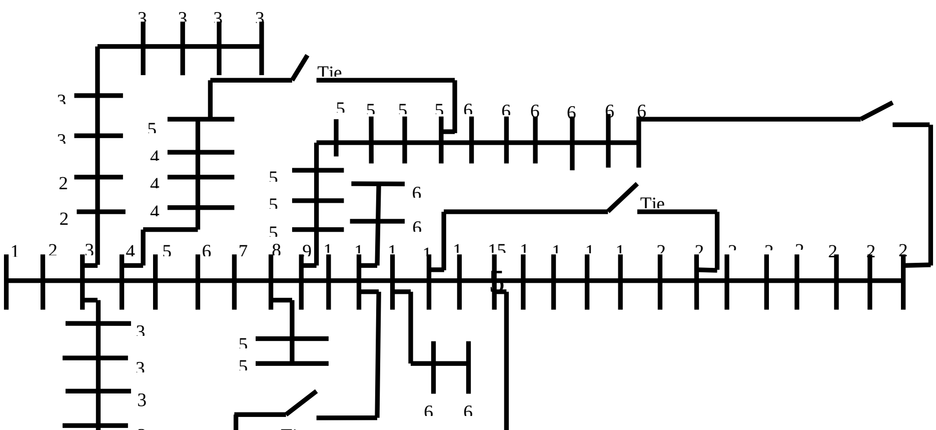


Figure 2 - The configuration diagram 33-Bus Radial Distribution System for constant power type load for load multiplying factor of 1.0.

B. 69-Bus System

The proposed methods are further implemented on 69-bus radial distribution system consisting of 73-branches. The single line diagram of 69-bus radial distribution system is shown in Figure 3 and the line data and load data are given in [11] with rated voltage of 12.66KV. To validate the effectiveness of the proposed method and to find optimal location, size of capacitor, results are compared with other techniques.



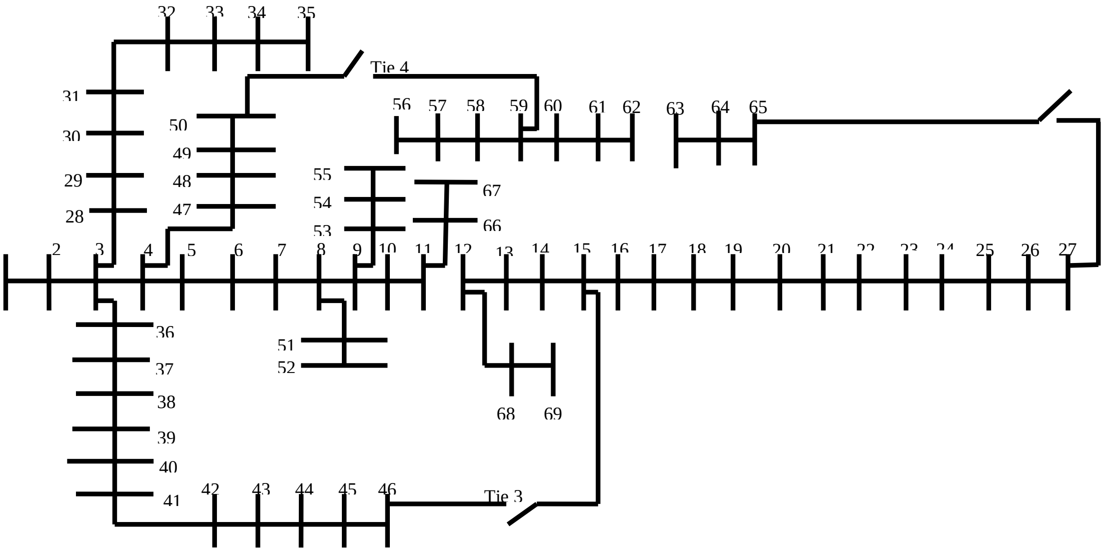


Figure 4: The configuration 69-Bus Radial Distribution System for constant power type load for load multiplying factor of 1.0.

Table 1:Results of 33-bus system with and without reconfiguration for constant power type load with multiplying factor 1.0

Without Reconfiguration				
Parameters	**Without Capacitor Placement**	**With Capacitor placement**		
		OKHA [12]	**MFO**	**QOBL-MFO**
Power Loss (KW)	210.998	153.80	147.23	131.01
Optimal position of capacitor	NA	30	29	29
Optimal size of Capacitor	NA	997.15	992.35	992.30
Opening branches	NA	NA	NA	NA
Closing branches	NA	NA	NA	NA
With Reconfiguration				
Power Loss (KW)		114.23	111.35	102.76
Optimal position of capacitor		27	27	27
Optimal size of capacitor		997.14	856.56	997.14
Opening branches		7-8 9-10 14-15 32-33	6-7 10-11 13-14 32-33	6-7 10-11 13-14 32-33

Closing branches	21-8 9-15 22-12 18-33	21-7 11-15 22-14 12-33	21-7 11-15 22-14 12-33

Table 2 – Results of 69-bus system with and without reconfiguration for constant power type load with load multiplying factor of 1.0

Without Reconfiguration					
Parameters	**Without Capacitor Placement**	**With Capacitor placement**			
		Fuzzy Approach [13]	**OKHA [12]**	**MFO**	**QOBL-MFO**
Power Loss (KW)	224.20	186.6	157.457	148.01	139.14
Optimal position of capacitor	NA	61	62	61	61
Optimal size of Capacitor	NA	400	974.10	998.32	998.32
Opening branches	NA	NA	NA	NA	NA
Closing branches	NA	NA	NA	NA	NA
With Reconfiguration					
Power Loss (KW)		95.10	67.653	65.325	59.07
Optimal position of capacitor		61	59	59	59
Optimal size of capacitor		400	985.23	997.14	985.23
Opening branches		57-58 64-65 12-13	55-56 62-63 11-12	55-56 62-63 11-12	55-56 62-63 11-12
Closing branches		50-59 27-65 15-46	50-59 27-65 15-46	50-59 27-65 15-46	50-59 27-65 15-46

6. CONCLUSION

This paper presents the QOBL-MFO based optimal reconfiguration model for enhancing the reliability of radial distribution systems. Also, this work intends to obtain an increased reliability of distribution systems with reduced power loss. Here, 33-bus and 69-bus systems are deployed for testing the efficacy of the proposed QOBL-MFO for optimal reconfiguration model. In addition to that, the obtained results are compared with the traditional optimization techniques for proving the superiority of the proposed model. Based on the analysis, it is identified that the proposed QOBL-MFO technique offers an improved results with reduced minimized power loss, when compared to the other techniques.

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