Binary PSO for Distribution Network Reconfiguration

Essam Mazloum Ali [1], Azza A ElDesouky[2], Gamal AbdulAzim[3]

Abstract— this paper proposes an effective approach based on Binary Particle Swarm (BPSO) optimization to identify the switching operation plan for feeder reconfiguration. Typical IEEE distribution systems consisting of 16 buses are used in order to validate the benefit of the proposed approach. The simulation result shows that the proposed method which applied to feeder reconfiguration problems is more effective and stable compared with other existing methods.

Keywords: Distribution systems, feeder reconfiguration, particle swarm optimization, BPSO.

1 Introduction

Reconfiguration of the radial distribution system has been under study for quite some time now for improving utility service and power quality. This is because of the losses caused in the distribution system that limit the network loadability. Almost of the distribution systems are designed to operate in radial configure and it have some of sectionalizing switches (Normally Closed) and tie switches (Normally Open). By performing switching operation with some conditions, the topology of the system can be alerted to get the best possible configuration to fit the required object function. In recent years, many researches have been produced the system losses minimization and improving system loadability in the area of network reconfiguration of distribution systems.

Many methods based on heuristics introduced to determine the minimum loss. Merlin and Back [1] had suggested all switches (sectionalized and tie switches) in close position and use the branch-and-bound method to open the required number of switches to restore the radial topology of the system in optimal operating configure. S. Civan1ar et al [2] have produced a different implementation of the branch-exchange method. They considered the open/close switches condition by using a discrete numbers.

On the other hand, a considerable number of researches are represented using the intelligent algorithms which have been modified to solve distribution network reconfiguration (DNR) problems. By help of fundamental loops Mendoza et al. [3] proposed a new methodology using genetic algorithm (GA) with directed mutation and reducing searching space. In [4] the objective was to minimize the total losses and improve the system loadability in distribution network by reconfigure the system using ant colony search algorithm. Wu et al. [5] improved the integer coded PSO method by adding historically optimal solutions to new particle creation, directing the search to optimization. This paper proposes a new method based on BPSO algorithm for distribution network reconfiguration problem.

- [1]*Testing and Commissioning Engineer, Port Said Networks (EETC), PH-0663409066. E-mail: e.mazloum@nece.com.sa*
- [2,3]*Electrical Engineering Department, Port Said University, Port Fouad 42523, Port Said, Egypt*

2 Binary Particle Swarm Optimization (BPSO)

Typical PSO was introduced by Kennedy and Eberhart [6] as a one of the artificial intelligent optimization methods inspired by nature. In the optimal problems any variable providing a new solution will represent as a particle and its limit will call a search D-dimension. Each separate particle has a optimal value evaluated by objective function to pick a good value for itself and population respectively. PSO launch a random number of particles of population. Each particle changed its searching area based on two best values "pbest & gbest" in each iteration. When pbest and gbest are obtained, a particle updates its velocity and hence its position. Based on Eq.1 and Eq.2 At last, the algorithm will check the results every iteration until the best solution is found or terminate conditions are satisfied.

$$v_{id}^{new} = wv_{id} + c_1 \times rand(1) \times (P_{best} - x_{id}) + c_2 \times rand(1) \times (G_{best} - x_{id}) \quad (1)$$

$$x_{id}^{new} = x_{id} + v_{id}^{new} \quad (2)$$

Where, v_{id}^{new}: The new value of the particle speed, i is the particle number and d is the selected search space number;

x_{id}^{new} : The new value of the particle speed;

P_{best} & G_{best} : are the best quantity of individual local and global search for each particle.

The PSO has been successfully applied to optimize various continuous function optimization problems. However, it is not designed for discrete function optimization problems. Fortunately, they proposed a new modified version of PSO called BPSO that can be used to solve discrete function optimization problems. In this BPSO, the typical PSO improved to solve the

discrete problem with idea of using probability of being '1' and '0' in binary space instead of position value is updated in the following equations for updating each bit of a particle

$$S(v_d) = \frac{1}{1+e^{-vd}} \qquad (3)$$

$$if \;\; S(v_d) = 0.5 \;\; then \;\; x_d = 0 \;\; else \;\; x_d = 1 \qquad (4)$$

Where, $S(v_d)$: The Sigmoid function for the particle speed v.

The sigmoid transformation to the velocity component Eq.3 is applied to squash the velocities into a range [0 or 0.5 or 1], and force the component values of the locations of particles to be 0's or 1's. Through Eq.4, in the DNR problem the closed switch represented by 1 and the open should be 0. By closing the tie line and start open the line section respectively one by one and calculate the velocity in each search space. Then, the individual P_{best} is updated for the test particle if the velocity result > 0.5, or stop and check another particle if the velocity <0.5. After check all particle dimension and update the $P_{best}$for each one and calculate the G_{best} and calculate the velocity vector for all particle.

3 Problem Formula

3.4 Radial load flow analysis (RLFA)

The algorithm radial load flow analysis RLFA is used to analyze the power flow in the tested radial distribution systems. By assuming the initial start voltage value in the first iteration at all busses is 1 p.u .with the given known load values at each bus , The expected load current in the first iteration can be calculated at each bus using Eq.5.

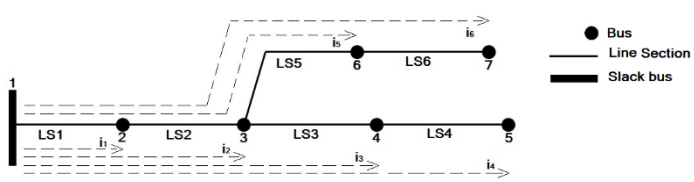

Fig-1 Simple 7th buses network

$$I_i^k = (P_i + JQ_i)/(V_i^k) \qquad (5)$$

Where,

I_i^k: The current passing in bus I for the iteration k;

V_i^k: The voltage value at bus i. for the iteration k;

P_i, Q: The active and reactive load at any bus i, respectively;

R_{ij}, X_{ij}: The resistance and reactance between bus i and j, respectively.

Based on the radial topology of the distribution system , a two develop matrices the node-injection to line section-current matrix (NILSC), and the line section-current to node-voltage matrix (LSCNV) which can be helpful for calculating the line section current (LSC) passing in each branch LS using Eq.6.

$$LSC_i^k = \sum_1^{bus-No} I_i^k \in LS_i \qquad (6)$$

$$V_{i-new}^k = V_{i-old}^k - \left(LSC_i \times \left(R_{ij} + JX_{ij}\right)\right) \qquad (7)$$

$$\Delta V = V_{i-new}^k - V_{i-old}^k \qquad (8)$$

$$P_{loss}^k = \sum LSI_i^2 \times R_{ij} \qquad (9)$$

$$Q_{loss}^k = \sum LSI_i^2 \times X_{ij} \qquad (10)$$

Where, LSC_i^k: The line section current for section i. at the iteration k;

LS_i: The line section for line i. , represent a number to define each line in the system

P_{loss}^k: The total active power loss for the system in iteration k.

Q_{loss}^k: The total reactive power loss for the system in iteration k

3.2. The objective function

The main aim of the objective function of the reconfiguration problem is to minimize the system Loses by reducing the real power losses and subjected to voltage and reactive power limits. Hence, the objective function has been performed by:

$$Minimize \quad f = \min\left(P_{loss}\right) \qquad (11)$$

The bus voltage magnitude and the required current of each bus must be maintained with the following range:

$$\begin{Bmatrix} V_{min} \le |V_i| \le V_{max} \\ I_i \le I_i^{max} \end{Bmatrix} \qquad (12)$$

Where, V_{max} and V_{min} are the maximum and minimum values of voltages and their values are taken as 1.05 and 0.9 p.u., respectively. The I_i^{max} is the maximum current at bus i

Also the feasible topology structure should be radial under normal conditions, and it shouldn't include any islanded system.

$$g \in G \qquad (13)$$

where g: The topology structure after reconfiguration.

G: The set of all feasible topology structures.

4 Simulation Results

The conventional PSO is modified based on the characteristics of distribution feeder operations. The IEEE 16 bus system is used to

validate the proposed method. The system operates at the nominal voltage of 12.66 kV (1 p.u) and the base apparent power is 10

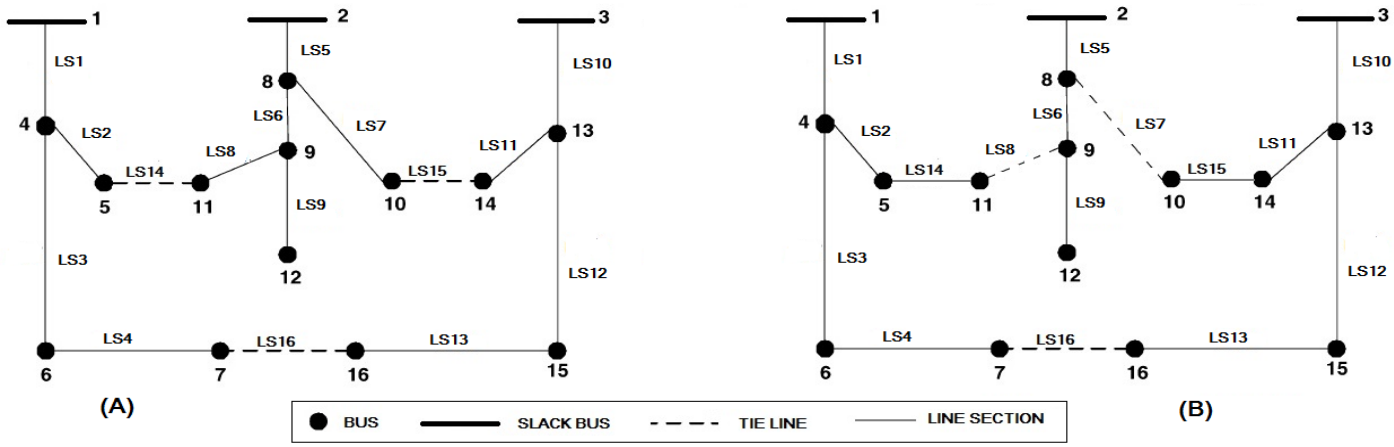

Fig-2 The IEEE 16 bus system
(a) On the basic configures
(b) After reconfigure with the proposed method

MVA. This system for reconfiguration case has 13 buses and 3 tie-lines. The normally open switches/lines are from LS14 up to LS16. The normally closed switches LS1 to LS13 are represented by the solid lines as shown in the Fig 2. The dimensions of the particles are:

Particle_1= LS14, Dimension is [LS1, LS2, LS8, LS6 and LS5]
Particle_2= LS15, Dimension is [LS5, LS7, LS11 and LS10]
Particle_3= LS16, Dimension is [LS3, LS4, LS13, LS12, LS11, LS15, LS7, LS6, LS8, LS14 and LS2]

The proposed method is programmed in MATLAB on a PC Core I3 1.86GHz computer with 2GB of RAM. The real power losses in initial network were equals to 511.398 KW and minimum voltage at bus 12 is 0.9693 pu. After preforming the propose method for the system the real power losses become 466.1 KW and minimum voltage at bus 12 is 0.9716 pu. The new system line arrangement is shown in Fig 2.b. The network data, line connection, line resistance and reactance value and the loads connected to buses, including the Voltage result at each bus are shown in table 1.

Table 1: results of IEEE16-bus system after reconfiguration

Branch Number	Sending Bus (i)	Receiving Bus (j)	Resist p.u	React p.u	Load at Receiving @Bus (j)		Voltage Result @ (j) p.u
					P (kW)	Q (kVAR)	
1	1	4	0.0750	0.1000	2.00	1.60	1.0000
2	4	5	0.0800	0.1100	3.00	0.40	1.0000
3	4	6	0.0900	0.1800	2.00	-0.4	1.0000
4	6	7	0.0400	0.0480	1.50	1.20	0.9907
5	2	8	0.1100	0.1100	4.00	2.70	0.9879
6	8	9	0.0800	0.1100	5.00	1.80	0.9860
7	8	10	0.1100	0.1100	1.00	0.90	0.9849
8	9	11	0.1100	0.1100	0.60	-0.5	0.9814
9	9	12	0.0800	0.1100	4.50	-1.7	0.9734
10	3	13	0.1100	0.1100	1.00	0.90	0.9900

11	13	14	0.0900	0.1200	1.00	-1.1	0.9878
12	13	15	0.0800	0.1100	1.00	0.90	0.9716
13	15	16	0.0400	0.0400	2.00	-0.8	0.9923
14	15	11	0.0400	0.0400	--	--	0.9907
15	10	14	0.0400	0.0400	--	--	0.9897
16	7	16	0.1200	0.1200	--	--	0.9891

Nominal voltage of the System 12.66 kV=1 p.u and the base apparent
power is 10 MVA, the Final losses after reconfiguration is 466.1 kW for active & 544.871kVAR for reactive

Fig. 3a & b shows the voltage profile and power losses at each bus after and before reconfiguration. From the results, it is proved that implementation of the proposed method in DNR problem has a high performance in very short time. Table-2 shows the comparison of the system losses before and after reconfiguration.

Table-2 Comparison results of different optimization techniques (16-bus system)

	Basic System Data	After Reconfiguration	ACSC	GA
Total power loss KW	511.398	466.1	466.5	466.5
Tie- switch	14-15-16	7 – 8 – 16	7 – 8 - 16	7 – 8 – 16
minimum voltage p.u @ bus	0.9693 @ 12	0.9716 @ 12	--	--
PCU time ms	1.1 ms	1.6 ms	--	--

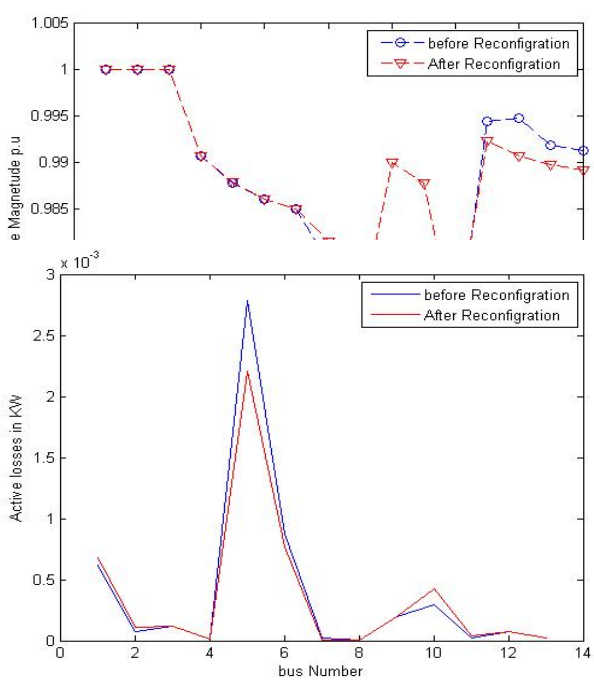

Fig-3 Simulation results
(a) System voltage profile before and after reconfiguration 3
(b) System losses at each bus in kW

4 Conclusion

This paper presents a BPSO optimization technique for solving distribution network reconfiguration DNR problem. The main advantage of this algorithm is its simplicity, fast and accurate in result. The proposed method is applied to the IEEE 16 Buses successfully. The result has proven the validity of the model.

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