BINARY PARTICLE SWARM OPTIMIZATION ALGORITHM – AN OPTIMAL ALGORITHM FOR NETWORK RECONFIGURATION IN DISTRIBUTION SYSTEMS

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Abstract

This paper proposes an alternative to solve the problem of reconfiguring the distribution network, with the aim of reducing the active power loss. Approximate methods are sufficient to solve it because it is an issue with complexity. Here, the proposition is a technique based on simple social behavior as a representation of the movement of organisms in a bird flock or fish school, namely Binary Particle Swarm Optimization algorithm, which is metaheuristic. Normally, in distribution systems network reconfiguration is usually done for reduction of losses, improvement of voltage, or for balancing the load in the system and this is carried out by changing the sectionalizing switch status. This technique is tested on distribution systems for IEEE 16-bus, IEEE 33-bus and IEEE 69-bus. The results suggest that reconfiguration is very helpful to reduce active power loss and improve the voltage profile in the Network when compared to base case, Genetic Algorithm (GA), Heuristic Approach and PSO.

***Keywords** :Network reconfiguration, Power loss reduction, Load flow, BPSO*

I.INTRODUCTION

Electrical power systems comprise three components: generation systems, transmission systems and distribution systems. The distribution system is a significant component of the electrical power system and is responsible for supplying energy to customers through transmission. The distribution system is designed as an interconnected network, but it must be operated in radial structure. Higher power losses occur at this stage. The losses of an electric system in Ideal condition should be around 3 to 6%. In developed countries, these losses are less than 10%. on the other hand, in developing countries, the active power loss percentage is around 20%. These losses cannot be eliminated but minimized by different techniques.

1) Elevation of network voltage profile and voltage drops compensation on its more critical sections by replacing or Adding step-up and phase-shifting transformers. Because of transformers excessive costs, this optimization technique is one of the most expensive.
2) Decreasing the cable electrical resistance, and consequently reduction in the Joule effect by Replacing all electrical cables and increasing its transversal section. it becomes a financially unfeasible solution Depending on the network extension.
3) Power Factor Correction by inserting Capacitor Banks at consumer load points, Installation of these devices require huge investment as capacitors are costly.
4) Improving the balance between active and reactive power on the electric network by inserting distributed generation (DG). Cost is high and DG could decrease the electrical network performance.
5) Changing the status of the switches by closing and opening to find a better combination for the optimization of the state of the electrical network.

It is essential to consider this reconfiguration technique, because it does not require electrical network installation or replacement of devices on Distribution network. The DNR problem has been studied since many years, Merlin and Back [1]proposed the method for Distribution system reconfiguration to reduce Power loss in the first place, where the authors use classic techniques and heuristics to find the less loss operatingreconfiguration in the distribution network., Optimal power flow analysis for network reconfiguration toreduce losses was proposed by Shirmohammdi and Hong [3]. Heuristic approach to reduce the search for switchingBaran and Wu [4] was proposed an algorithm. Goswami and Basu [5] discussed a heuristic algorithm based on theoptimum flow pattern. Different optimization algorithms for loss reduction are employed in [6-11 ,15,17-19]. In recentyears,the fast development of distributed generations led to compensation of both active and reactive power. Byemploying different optimization techniques in [12-14], the optimal locations and sizes have been employed.

In this paper, proposed technique is based on Binary particle swarm optimization algorithm (meta heuristic) to solve DNR problem by determining the minimum loss configuration of a radial distribution system. all the tie switches are kept in open position with initial configuration at the beginning of this method. it is not necessary to open the sectionalizing switches further in the loop if the power loss due to other sectionalizing switches is greater than the current losses.

II.PROBLEM FORMULATION

The network reconfiguration problem in a distribution system is to obtain the configuration with minimum loss while satisfying the operating constraints. The operating constraints are voltage drop, current capacity and radial operating structure of the system. The mathematical formulation for the minimization of power loss in reconfiguration problems is formulated as,

A. *Objective Function and Constraints*

For obtaining the objectives of this network reconfiguration technique, the problem is defined mathematically as an objective function (OF) for optimization,

Minimize $f = \min(P_{T,Loss})$ (1)

Subject to:

a) Node voltage constraint:

Voltage magnitude at each node must lie within their permissible ranges to maintain power quality

$$0.95 \le V_i \le 1.05 \quad (2)$$

c) Generator operation constraints:

All DG units are only allowed to operate within the acceptable limit where $P_i^{\min}$ and $P_i^{\max}$ are the lower and upper bound of DG output.

$$P_i^{\min} \le P_g \le P_i^{\max} \quad (3)$$

d) Feeder capability limits:

$$\left|I_k\right| \le I_k^{\max} \;\; k \in \{1, 2, 3, \ldots\ldots l\} \quad (4)$$

Where, I_k^{max}= maximum current capability of branch k.

B. *Optimal Load Flow Calculation*

As the distribution systems have low line X/R ratios, distribution networks will be ill-conditioned for the calculation of voltage and currents at each bus and branch using conventional load flow methods. Other than that, the load flow method of distribution system should have efficient time and robust characteristics. Therefore, backward-forward sweep method is employed as distribution load flow technique to calculate currents of each branch (Ibr).

1. Backward Propagation: The backward sweep starts at the extreme end node and proceeds towards source node. The voltage ( ) values obtained in the forward path are held constant during the backward propagation and power flows ( ) at each branch updated are transmitted backward using backward path along the feeder. The current at each bus is computed as,

$$i_b^k(b) = \frac{S_b^k(b)}{V_b^k(b)} \qquad (5)$$

The current of each branch is then calculated as the current difference between last branch and last bus from the end node i.e.

$$i_{br}^k(br) = i_{br}^k(br-1) - i_b^k(b) \qquad (6)$$

2. Forward propagation: The voltage at each node starting from the source node of feeder is calculated in the forward sweep. Here, the effective power in each branch is held constant to the obtained value in the backward sweep. Voltage at each bus is calculated as voltage difference between last bus and last branch from the starting node to the last one.

$$V_b^k(b+1) = V_b^k(b) - Z_{br}(br) i_{br}^k(br) \qquad (7)$$

Zbr(br) represents the impedance of each branch. The voltages calculated in the previous and present iterations are compared for the convergence criteria. ‘k’ here in all equations is the iteration count. The procedure is repeated until the voltage of each bus is converged i.e., $\Delta V_b^k(b) \le \varepsilon(tolerance)$ is satisfied in

$$\Delta V_b^k(b) = V_b^k(b) - V_b^{k-1}(b) \qquad (8)$$

III. PROPOSED METHOD

The BPSO algorithm was introduced by Kennedy and Eberhart to allow the PSO algorithm operation in binary problem spaces. It uses the concept of velocity as a probability that a bit (position) takes on one or zero.The BPSO algorithm is initialized with the population of individuals being randomly placed in the search space and search for an optimal solution by updating individual generations. At each iteration, the velocity and the position of each particle are updated according to its previous best position and the best position found by informants. In the original continuous version, each particle’s velocity and position are adjusted by the following formula:

$$v_{i,j}(t+1) = wv_{i,j}(t) + c_1R_1(p_{best,i,j} - x_{i,j}(t)) + c_2R_2(g_{best,i,j} - x_{i,j}(t)) \qquad (9)$$

$$x_{i,j}(t+1) = x_{i,j}(t) + v_{i,j}(t+1)$$

Where, C1 , C2 are the acceleration coefficients,

w is the inertia parameter,

R1 , R2 are random variables ,

g_b is the global best and

p_b is the best position of the particles.

The acceleration coefficients, c1 and c2finds the influence of the personal best and the neighborhood best solutions on the particle's current velocity vector The inertia parameter, w controls the influence of the previous velocity on the current velocity, it was shown that a good convergence can be obtained by making these two constants (acceleration and inertia) dependent. The relation between acceleration parameters and inertia parameter is shown in equation(12) with an intermediate parameter. In this paper C1 and C2 values are taken as 2.

$$w = \frac{1}{\varphi - 1 + \sqrt{\varphi^2 - 2\varphi}} \qquad (10)$$

$$c_1 = c_2 = \varphi w$$

Where,φ is an intermediate parameter.

In the BPSO, Eq. (9) for updating the velocity remains unchanged, but Eq. (10) for updating the position is redefined by the rule.

$$x_{i,j}(t+1) = \begin{cases} 0 if rand\,() \geq S(v_{i,j}(t+1 \\ 1 if rand\,() < S(v_{i,j}(t+1 \end{cases} (11)$$

Where, $S(.)$ is the sigmoid function for transforming the velocity to the probability as the following expression:

$$S(v_{i,j}(t+1)) = \frac{1}{1 + e^{-v_{i,j}(t+1)}} \qquad (12)$$

rand () is the pseudo-random number selected from a uniform distribution over [0, 1]. For a velocity of 0, the sigmoid function returns a probability of 0.5, resulting that there is a 50% chance for the bit to flip.

IV.RESULTS AND DISCUSSIONS

The proposed algorithm is implemented on radial distribution systems of IEEE 16-bus, IEEE 33-bus and IEEE 69-bus with sectionalizing and tie switches. the importance and effectiveness of the proposed method is explained by using distribution network. implementation is carried out in MATLAB on a PC Intel I3 Processor, 1.8-GHz computer with 4 GB RAM.

16-Bus

for the reconfiguration, the 16-bus distribution system[18] consists of 16 buses and 3 tie lines. In the figure 1, switches from 1 to 13 are indicated in solid lines which are normally closed switches and the switches 14, 15 and 16 are indicated in dotted lines which are the normally open tie switches.

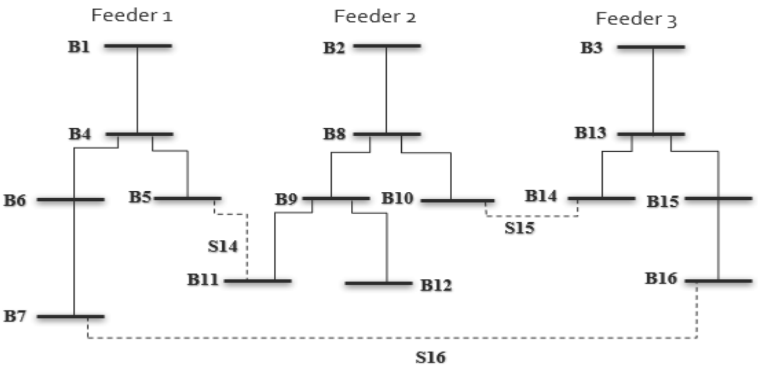


Fig.1, IEEE 16–Bus Initial configuration of the radial distribution system

TABLE I

	Before reconfiguration	***After reconfiguration***
Tie switches	14 15 16	7 8 16
Power loss	514.0293 kW	468.3304 kW
Power loss reduction	----------------	8.8903 %
Minimum voltage	0.96824 pu	0.9707 pu

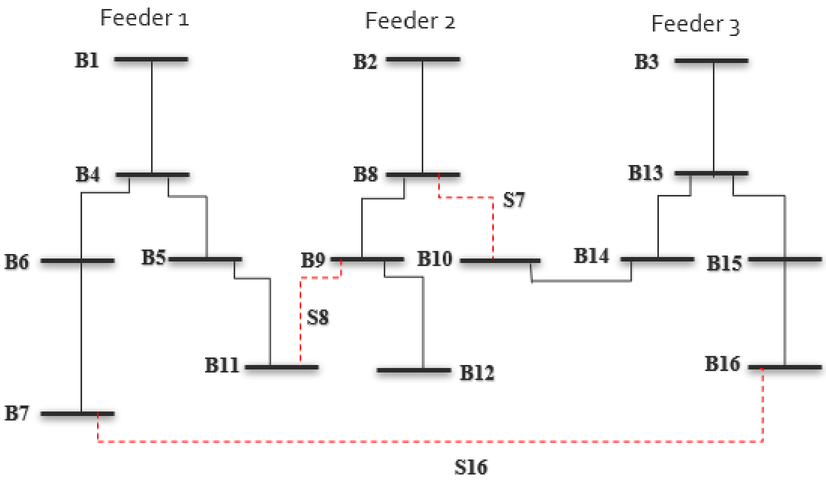


Fig.2, IEEE 16–Bus final configuration of the radial distribution system after all the switching operations by using BPSO algorithm, the optimal configuration of the 16-bus radial distribution network is shown in figure 2, with new tie switches of 7, 8 and 16. the simulation results of the base configuration and the optimal configuration is shown in Table I. The minimum and the maximum voltagesof the two base and optimal configurations are 0.96824 pu and 0.9707 pu respectively which areshown in figure 3. before reconfiguration, the power loss is 514.0293 kW and after reconfiguration it is reduced to468.3304 kW. From the results, it is observed that reduction in power loss is 45.6989 kW which is approximately 8.8903 %.

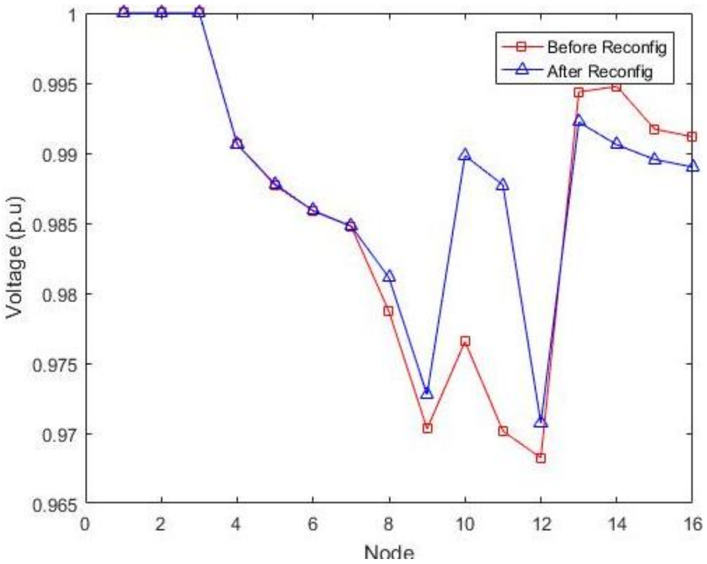
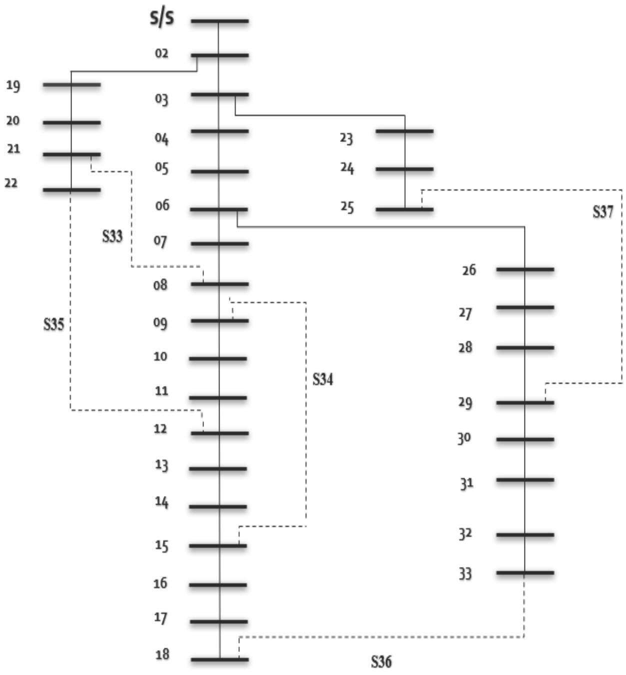


Fig. 3 IEEE 16–Bus System Voltage Profile.

33-Bus

for the reconfiguration, the33-bus distribution system[17] consists of thirty-three buses and five tie lines. In the figure 4, switchesfrom 1 to 32 are indicated in solid lines which are normally closed switches and the switches 33, 34, 35, 36, and 37 are indicated in dotted lines which are the normally open tie switches.

after all the switching operations by using BPSO algorithm, the optimal configuration of the 33-bus radial distribution network is shown in figure 5, with new tie switches of7, 9, 14, 32 and 37. the simulation results of the base configuration and the optimal configuration is shown in Table II. The minimum and the maximum voltages of the two base and optimal configurations are 0.91075 pu and 0.94234 pu respectively which are shown in figure 6. before reconfiguration, the power loss is 208.4592 kW and after reconfiguration it is reduced to 101.9275 kW. From the results, it is observed that reduction in power loss is 106.5317 kW which is approximately 51.1043%.



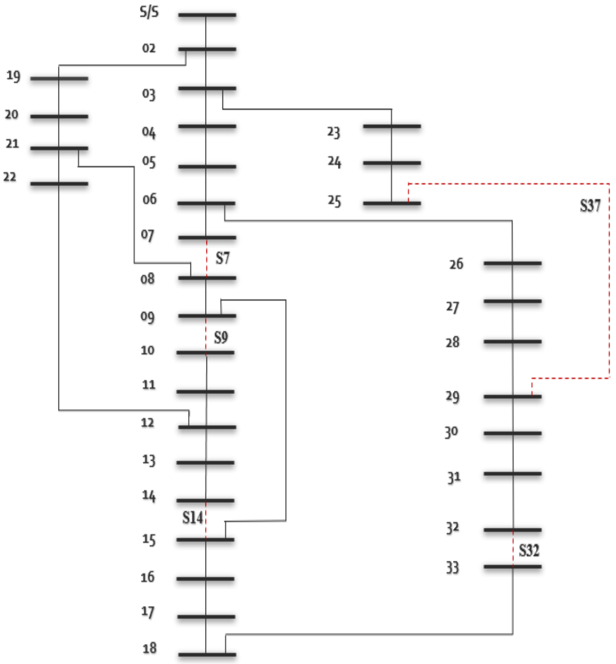


Fig.4, IEEE33–Bus initial configuration of the distribution system

Fig.5, IEEE33–Bus final configuration of the radial radial distribution system

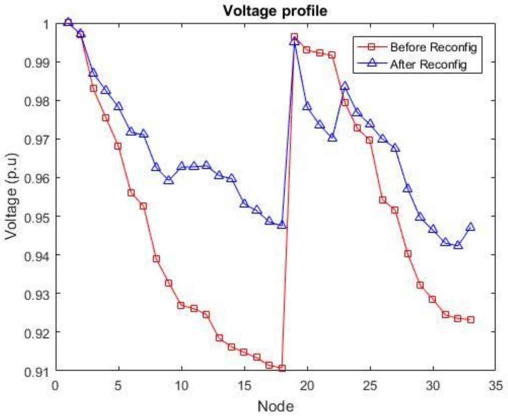


Fig. 6 IEEE 33–Bus System Voltage Profile.

Table II

	Before reconfiguration	*After reconfiguration*
Tie switches	33 34 35 36 37	7 9 14 32 37
Power loss	208.4512 kW	101.9207 kW
Power loss reduction	--------------	51.1057 %
Minimum voltage	0.91075 pu	0.94234 pu

69-Bus

for the reconfiguration, the 69-bus distribution system consists of 69 buses and 5 tie lines. In the figure 7, switches from 1 to 68 are indicated in solid lines which are normally closed switches and the switches 69, 70, 71, 72 and 73 are indicated in dotted lines which are the normally open tie switches.

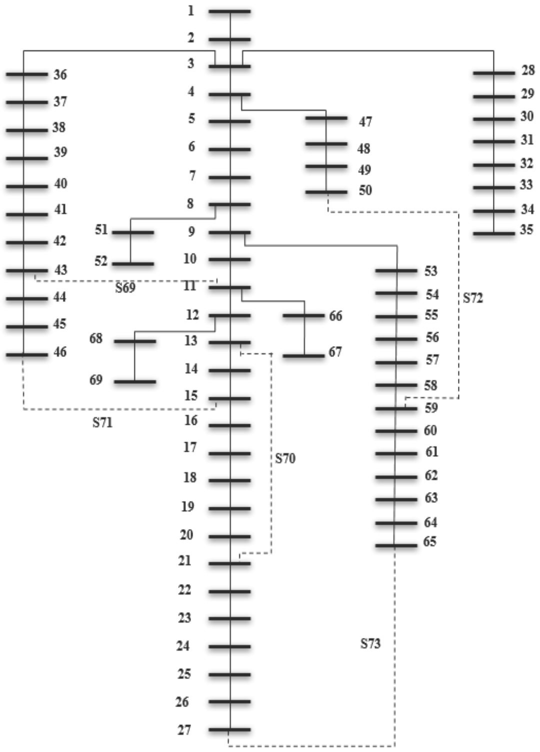


Fig.7, IEEE69–Bus initial configuration of the radial distribution system

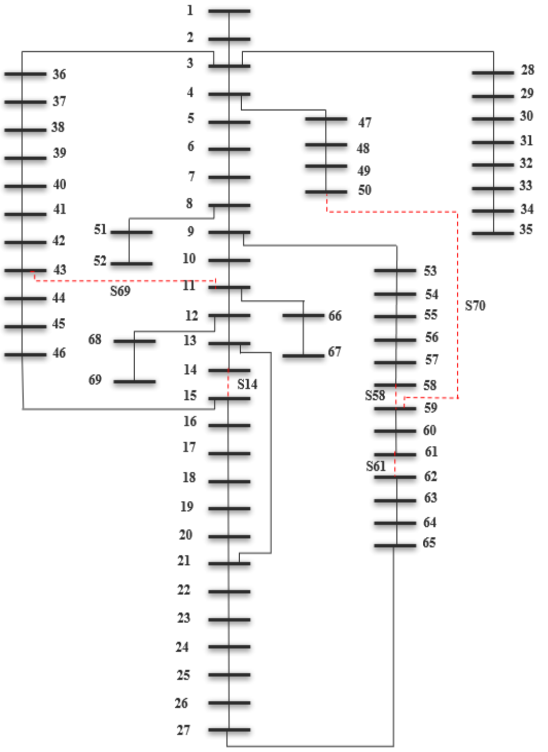


Fig.8, IEEE69–Bus final configuration of the radial distribution system

after all the switching operations by using BPSO algorithm, the optimal configuration of the 69-bus radial distribution network is shown in figure 8, with new tie switches of 14, 58, 61, 69 and 70. the simulation results of the base configuration and the optimal configuration is shown in Table III. The minimum and the maximum voltages of the two base and optimal configurations are 0.90919 pu and 0.94947 pu respectively which are shown in figure 9. before reconfiguration, the power loss is 224.9804 kW and after reconfiguration it is reduced to 98.5952 kW. From the results, it is observed that reduction in power loss is 126.3852 kW which is approximately 56.1761%.

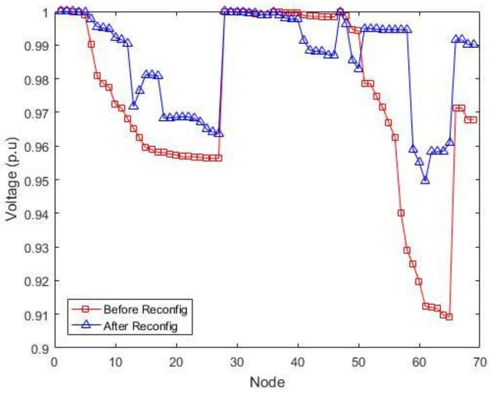


Fig. 9 IEEE 69–Bus System Voltage Profile.

Table III

	Before reconfiguration	***After reconfiguration***
Tie switches	69 70 71 72 73	14 58 61 69 70
Power loss	224.9804 kW	98.5952 kW
Power loss reduction	--------------	56.1761 %
Minimum voltage	0.90919 pu	0.94947 pu

V.COMPARISION OF RESULTS

Comparison for 33 bus

The proposed method is compared with Heuristic Approach, Particle swarm optimization (PSO) and Genetic Algorithm (GA) along with base case for the same 33-bus test system. For effective comparison, the results of the proposed method along with other method are shown in Table IV.

Table IV

Method	Before Reconfiguration	Heuristic Approach	PSO[19]	GA[20]	**BPSO**
Total loss (KW)	208.45	111.12	138.927	146.50	**101.9**
Total loss savings (%)		46.7	33.355	27.694	**51.1043**
Minimum voltage (p.u)	0.91075		0.94124	0.938	**0.94234**

Comparison for 69 bus

The proposed method is compared with bacterial foraging optimization algorithm with particle swarm optimization strategy (BF-PSO) &Refined Genetic Algorithm (RGA) with base case for the same 69-bus test system. For effective comparison, the results of the proposed method with other method are shown in Table V.

TABLE V

Method	Before Reconfiguration	RGA[21]	BF-PSO[22]	**BPSO**
Total loss (KW)	224.9804	102.100	99.670	**98.5952**
Total loss savings (%)		54.1682	55.6983	**56.1761**
Minimum voltage (p.u)	0.90919	0.926	0.943	**0.94947**

VI.CONCLUSION

In the present work, the network reconfiguration problem is solved optimally to achieve the lowest power loss in the distribution systems. The minimum power losses with improved voltage profile can be achieved by using optimal network reconfiguration while observing all possible combinations of switching automatically. The proposed BPSO algorithm has been tested on the IEEE 16-bus, IEEE 33-bus and IEEE 69-bus systems. The results show that the power loss is minimized compared to different techniques. Results also indicate that there is a significant improvement of voltage stability for most of the buses, but thetime taken for obtaining optimal solution is more compared to Heuristic method.

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