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AACO technique for solving multiobjectives in electrical distribution system

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Article Info	ABSTRACT
	The multi objectives in electrical distribution system are service restoration and minimization of Ohmic losses. These objectives can be achieved by artificial ant colony optimization through reconfiguration. Service restoration is also a major aspect for reliable service. If any fault occurs in the system, faulted zone is isolated from healthy system. This originates discontinuity in power supply. To maintain the continuity in power supply there is a necessity to provide service to these loads from adjacent healthy feeders through reconfiguration without infringement of radiality, load balance and critical parameters. In distribution system Ohmic losses are 30 to 40 percent. In order to minimize these losses, there is a need for reconfiguration of the system and perform the power flow analysis to get bus voltages, branch currents and power losses (i.e. real or Ohmic or copper loss and reactive power loss). A direct load flow analysis is adopted in the proposed work. In this paper IEEE four feeder test system used for service restoration and IEEE 33 bus, IEEE 69 bus test systems for minimization of Ohmic losses have been obtained.

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1.   INTRODUCTION

Generation, transmission and distribution are the three stages of electrical power system. Generating power at generating station is transmitted through transmission lines and given to distribution network. It distributes power to loads connected to distribution network. Electrical distribution system is operated for lower voltages compared to transmission system. Because of lower voltage, higher currents pass in distribution system this lead to higher real power loss compared to generation and transmission systems. Distribution system is operated with fixed voltage and variable current magnitudes. In any environment three main important factors are existed. Those are security, reliability, efficiency (priority of choosing among three are security, reliability, efficiency).

If any fault occurred in system, that may create cascade shutdown then overall system collapse. To avoid this should take immediate actions. Actions are may be isolated faulted zone in the system and give supply to remaining loads from healthy feeders, in some cases the remaining healthy feeders are already in overload condition then go for load shutdown at this moment system safety important role. This is nothing but service restoration, this may not provide 100% continuous power supply but somehow it maintains both reliable supply and system safety.

The apparent power loss is equal to sum of real and reactive power losses. If power losses (apparent power loss) increases then real and reactive power losses also increases. Real power loss is more means system with less efficient. Reactive power is directly proportional to square of voltage in the system.

If reactive power is more, then voltage in the system more this lead to insulation breakdown on conductor finally dead short circuit will occur then overall system collapse, so need to maintain minimum apparent loss then it results good efficiency and voltage in the system.

Power loss reduction formula is derived by Civanlar & Grainger [1], in this paper power loss reduction and reduced computation time done by using "branch interchange" algorithm. D. Shirmohammadi & H. W. Hong [2], in this paper the researcher focused on both resistive loss reduction and reduced computed time using DISTOP methodology. M.E. Baran & F.Wu [3], in this paper author applies two different load flows for the sake of accuracy and computation time. Both loss reduction and load balance achieved by using approximated power flow methods. Taylor, Lubkeman [4], developed a rule –based system aimed at the reduction of both search space and real power loss. J.Z. Zhu [5], presented to study distribution network reconfiguration based on refined genetic algorithm. A radiation distribution network load flow method is used to calculate power losses and objective is to minimize the system power loss. Jorge Mendoza et al [6], proposes a formal and robust strategy for applying the large optimal reconfiguration problems using genetic algorithm. The main objective is to power loss minimization through reconfiguration. The problems of overloading and service restoration, unbalanced load on electrical distribution system can be solved through reconfiguration by using ant colony optimization and heuristic search technique [7], [8] respectively. F.S Pereira, K. Vittori et al [9], proposed meta heuristic methodology for reconfiguration of electrical distribution system to minimize power loss. In this paper two algorithms ant colony optimization-travelling salesman and ant colony optimization-radial system reconfiguration are applied to one common standard five bus sample system. Finally author justified ant colony optimization-radial system reconfiguration is best for reconfiguration. Majid Jamil et al [10], proposed for the restoration of electrical distribution system in the overload condition with minimum power loss by using ant colony system algorithm. Firas M.F.Flaih,Lin, Lin Xiangning et al [11], presented the power loss minimization and voltage profile improvement in distribution system by using modified particle swarm optimization, modified particle swarm optimization was applied on the standard IEEE 33-bus test system. Other heuristic methods have been published that are principally based on switch selection(reconfiguration) done by using modified particle swarm optimization, Multi-Cooperative Particle Swarm Optimization, Selective Particle Swarm Optimization algorithms solved for IEEE 33 & 69 bus test systems. The objective function is to power loss minimization and approximate formulas for losses evaluation as those presented in [12], [13] and [14] respectively. S.Ganesh and R.Kanimozhi [15], proposed a new method for network reconfiguration in distribution system based on ant colony optimization with objective of real power loss minimization for 33-bus single feeder distribution network with five different kinds of load levels. Real loss minimization through reconfiguration of radial distribution system in both normal and abnormal conditions done with Improved Particle Swarm Optimization was projected by Dusharal Venkata Sunil et al [16].

In this paper, reconfiguration of distribution system has been formulated by using Artificial Ant Colony Optimization technique. Next output of any system with linear characteristics can be easily predicted but practically linear behaviour is not present. Nonlinear behaviour cases cannot predict next output, as it is very complex. This technique gives the solution to nonlinear problems, reduces time consumption and gives accurate results. This technique is co-related with electrical distribution system as current matches with ant's movement, pheromone intensity matches with power flow and length of the line with resistance or time consumption. Two objectives are met, first one is service restoration and second one is real power loss minimization. The proposed work is organized into six sections, first Section-1 is introduction, Section 2 on problem formulation, Section 3 discusses proposed technique algorithm for reconfiguration, and Section 4 discussed proposed method applications on test systems. Section 5 on results and finally conclusions are in Section 6.

2. PROBLEM FORMULATION
2.1. Service Restoration

First identify faulted feeder, isolate the fault. Identify the affected zones due to fault, which are out of service. Reconfigure the system with LBI calculations using (1).

$$LBI = \frac{1}{n}\sqrt{\sum(Y - Y_i)^2} \tag{1}$$

Where: n= no. of primary feeders; Y=average of the normalized loadings Y_i

$$Y_i = \frac{i^{th} - \text{Feeder Actual Loading}}{i^{th} - \text{Feeder Base Loading}} ; i=1, 2, 3….n$$

Subjected to following constraints:

$S_i \le S_{Ri}$

$P_i \le P_{Ri}$

$Q_i \le Q_{Ri}$

Where: i=1, 2, 3….n; n= no. of primary feeders

S_i=MVA loading on feeder – i ; S_{Ri}=Rated MVA on feeder - i

P_i=MW loading on feeder – i; P_{Ri}=Rated MW loading on feeder - i

Q_i=MVAR loading on feeder – i ; Q_{Ri}=Rated MVAR on feeder – i

In each and every reconfiguration load should be in balance condition, radiality and critical parameters with in permissible limits. Among all possible combinations which one gives least LBI value and satisfies all critical parameters that is the optimal solution.

2.2. Power Flow Analysis - Direct Load Flow Method (DLFM)

This method performs the power flow analysis for weakly meshed distribution system under balanced operating condition employing constant load model. In this method three steps are present, those are

a. Equivalent current injection

b. Formation of BIBC matrix

c. Formation of BCBV matrix

2.2.1 Equivalent Current Injection

It is purely based on current injection. At i^{th} bus, the apparent power S_i is specified and the corresponding equivalent current injection at the nth iteration of the solution is computed as:

$$S_i = P_i + jQ_i \tag{2}$$

$$I_i^n = \left(I_i^{Real} V_i^n\right) + j\left(I_i^{Img} V_i^n\right) = \left(\frac{S_i}{V_i^n}\right)^* \tag{3}$$

Where: i=1, 2, 3, 4… N

S_i is the apparent power at i^{th} bus; P_i is the real power at i^{th} bus.

Q_i is the reactive power at i^{th} bus; V_i^n is the bus voltage at the nth iteration for i^{th} bus.

I_i^n is the equivalent current injection at the nth iteration for i^{th} bus.

I_i^{Real} & I_i^n are the real and imaginary parts of the equivalent current injection at the nth iteration for i^{th} bus.

2.2.2 Formation of BIBC Matrix

In Figure 1 is used as an example to understand the formation of BIBC matrix. Using (3) apply Kirchhoff current law (KCL) to distribution network.
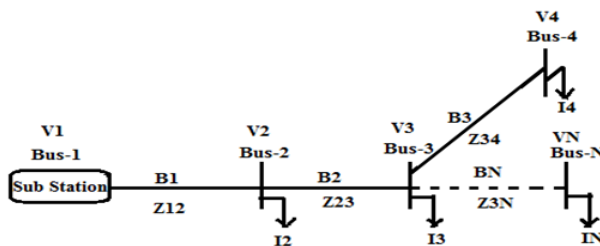

Figure 1. A simple weakly meshed distribution system

$$B1 = I2 + I3 + I4 \tag{4}$$

$$B2 = I3 + I4 \tag{5}$$

$$B3 = I4 \tag{6}$$

Above (4), (5), (6) can be written in matrix form. This matrix is nothing but BIBC (Bus Injection to Branch Current) matrix as shown below (7).

$$\begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_2 \\ I_3 \\ I_4 \end{bmatrix} \tag{7}$$

$$[B] = [BIBC]_{MX(N-1)}[I] \tag{8}$$

Where:

B_1, B_2, B_3……B_N are the branch currents.

V_1, V_2, V_3…..V_N are the bus voltages.

Z_{12}, Z_{23}, Z_{34}…..Z_{3N} are the branch impedances between 1and2, 2 and 3, 3 and 4, 3 and N respectively.

I_2, I_3, I_4………I_N are the load currents.

M is the number of branches.

N is the number of buses.

2.2.3 Formation of BCBV Matrix

BCBV matrix nothing but, it is the relation between branch currents and bus voltage.

$$V_1 = V_2 + (B_1 * Z_{12}) \tag{9}$$

$$V_2 = V_3 + (B_2 * Z_{23}) \tag{10}$$

$$V_3 = V_4 + (B_3 * Z_{34}) \tag{11}$$

By using above (9), (10) and (11) the voltage at Bus-4 can be rewritten as

$$V_4 = V_1 - (B_1 Z_{12}) - (B_2 Z_{23}) - (B_3 Z_{34}) \tag{12}$$

Above (9), (10), (11) and (12) can be written in matrix form. This matrix is nothing but BCBV (Branch current to Bus Voltage) matrix as shown below (13).

$$\begin{bmatrix} V_1 \\ V_1 \\ V_1 \end{bmatrix} - \begin{bmatrix} V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} Z_{12} & 0 & 0 \\ Z_{12} & Z_{23} & 0 \\ Z_{12} & Z_{23} & Z_{34} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} \tag{13}$$

$$[\Delta V] = [BCBV]_{(N-1)XM}[B] \tag{14}$$

$$I_i^n = \left[\frac{P_i + Q_i}{V_i} \right]^* \tag{15}$$

Update voltages using (14), Calculate DLF (direct load flow) matrix using (16)

$$[\Delta V]^{n+1} = [DLF][I]^n \tag{16}$$

Set iteration count n=0, if $|[I_i^{n+1} - I_i^n]| < \xi$ (tolerance value) then calculate line flows and losses using final voltages. Otherwise go for iteration number increment (n=n+1) and follow above same procedure.

Subject to the following constraints:

a. Radiality to be maintained.

b. Number of tie switches before and after reconfiguration should not change.

c. Voltage Magnitude:

$$V_{min} \leq |V_i| \leq V_{max} \ ; i \tag{17}$$

Where:

V_i is the voltage on i[th] bus; N_R is the number of branches in the system; N_b is the number of buses in the system. These constraints are applicable to all Objectives.

3.   PROPOSED TECHNIQUE - ARTIFICIAL ANT COLONY OPTIMIZATION (AACO)
3.1.   Introduction
This technique gives solution to nonlinear problems related to any field of work. Natural living behavior of ants gives optimal solution either a minimal or a maximal of main objective of problem is called Ant Colony Optimization.

When an ant moves to search for food from home to food source it deposits chemical substance on ground called as pheromone. This substance is a clue for other ants from the same home to collect the food. Ants follow the pheromone trails left by the first ant. From home to food source the ants have several paths with variable pheromone trails. Among those trails ants choose higher pheromone intensity path. This path is also attracted by remaining ants. Always ants prefer shortest path (i.e. higher pheromone intensity).

Figures 2 and 3 represent ant colony system without and with obstacle. Thicker line indicates higher pheromone intensity as a shorter path, thinner line indicates less pheromone intensity as a longer path.
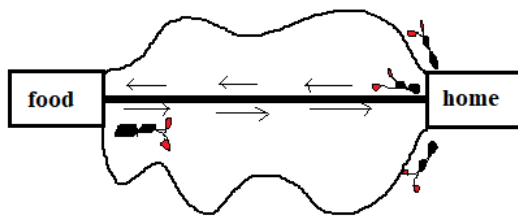

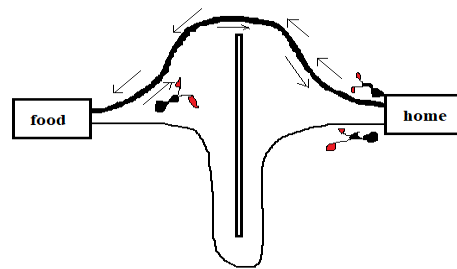Figure 2. Natural behavior of ant without obstacle

Figure 3. Natural behavior of ant with obstacle

Electrical Distribution System having n= number of switches and total possible combinations for reconfiguration are 2^n. In order to reduce time consumption for this possible reconfigurations ACO itself has probabilistic transition rule (PTR).

PTR measures ant probability of choosing path among all possible paths. For example when a system has 10 switches then total number of possible combinations for reconfiguration are $2^{10}=1024$. Using PTR this may reduce to 15 possible combinations for reconfiguration and gives optimal solution.
PTR is formulated as (18)

$$P_{i,j}^k(t) = \frac{[\tau_{i,j}(t)]^\alpha [\eta_{i,j}(t)]^\beta}{\Sigma_l [\tau_{i,j}]^\alpha [\eta_{i,j}]^\beta} \qquad (18)$$

Where: $j, q \in N_i^k$.
N_i^k is a list in the memory of ant that records the cities which will be visited to avoid stagnations.
i, j is the travel path of ants; $\tau_{i,j}$=pheromone trail deposited between the nodes i, j.
$\eta_{i,j}$==represents the heuristic information=$\frac{1}{d_{i,j}}$; $d_{i,j}$= distance between city i and j.
$\propto, \beta$ =Are two parameters that influence the relative weight of pheromone trail and heuristic guide function respectively.

After each tour is completed a local pheromone update is determined as below mentioned (19). It is the sum of old pheromone intensity $(\rho. \tau_{i,j}(t))$ and new pheromone intensity $(\Delta\tau_{i,j})$.

$$\tau_{i,j}(t+1) = (\rho. \tau_{i,j}(t) + (\Delta\tau_{i,j}) \qquad (19)$$

Where:
$\Delta\tau_{i,j} = \sum_{i=1}^l \Delta\tau_{i,j}^k$
$\Delta\tau_{i,j}^k = \frac{Q}{L_k}$, if ant k travels on edge (i, j) otherwise it is zero; t =iteration counter; k= 1, 2....l ants.
Q=constant; L_k=length of tour.

3.2. Flow Chart

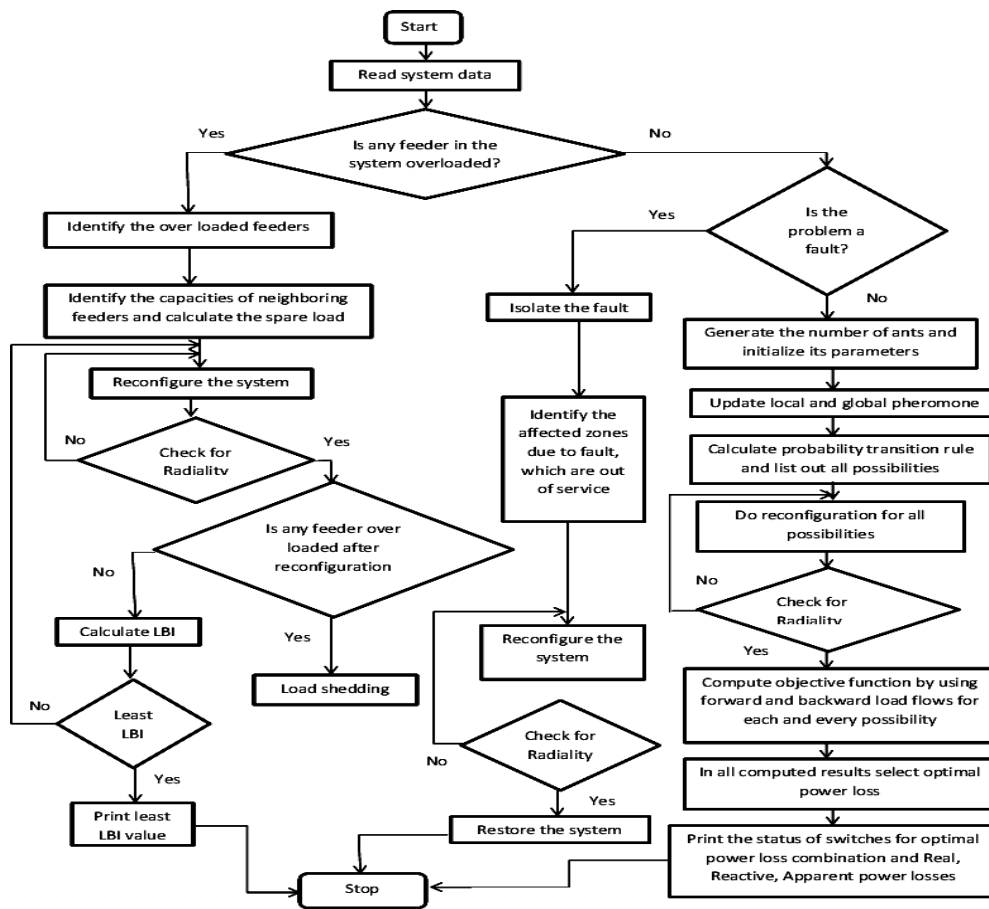Flowchart of proposed method is shown in Figure 4.

Figure 4. Flowchart of proposed method

4. PROPOSED METHOD

The proposed AACO method is tested on four feeder service restoration, Ohmic loss minimization of IEEE 33 bus and 69 bus test systems. Test results as follows below.

4.1. IEEE Four Feeder Service Restoration

The proposed AACO technique is tested on the IEEE four feeder test system is shown in Figure 5, in this 16 sectionalized switches are generally in closed condition(between zone loads example-switches 2,3,4…) and 15 tie switches are generally open condition (between zone loads of different feeders example-switches 6,7,8…). Each feeder loading capability is 10,000 kVA.1, 11, 21, 31 are the circuit breakers of four feeders in the system. Table 1 shows the zone loads.
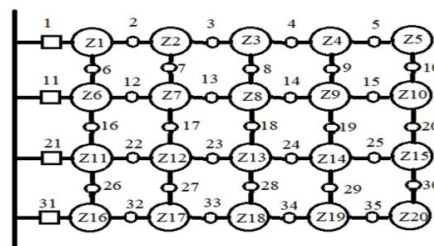

Figure 5. Four feeder test system

Table 1. Four Feeder Load Data

Zone number	Zone load(kVA)
1	1600
2	700
3	1800
4	500
5	1900
6	500
7	1500
8	1000
9	500
10	800
11	3000
12	3500
13	700
14	1000
15	600
16	1500
17	2000
18	1800
19	1500
20	500

From Figure 5, each feeder capacity is 10000 kVA and actual load on feeder A, B, C and D is 6500 kVA, 4300 kVA, 8800 kVA, 7300 kVA respectively. For illustration of the proposed technique, assume some random faults occur on four feeder system (i.e. feeder A, B, C and D at positions are Z1, Z8, Z14 and Z17 respectively).these random faults explained in below four cases.

Case-1: Fault on feeder A at switch-1(circuit breaker)

Because of fault at switch-1, faulted section is isolated by opening Switch-1(Circuit breaker).To maintain continuous power supply need to connect total (Or) at least some of critical loads are transfer to other healthy feeders.

Before Reconfiguration: load on feeder A is zero kVA, feeder B is 4300 kVA, feeder C is 8800 kVA and feeder D is 7300 kVA.

After Reconfiguration: Switches 6, 20 are closed condition (sectionalized Switches), Switch 15 is in open condition (tie switch).Load on feeder A is zero kVA, feeder B is10000 kVA, feeder C is 9600 kVA and feeder D is 7300 kVA.

Case-2: Fault on feeder B at position Z8

Because of fault, faulted section is separated by opening switches 13 and14. Discarded load on feeder B is 2300 kVA.

Before Reconfiguration: load on feeder A is 6500 kVA, feeder B is 2000 kVA, feeder C is 8800 kVA and feeder D is 7300 kVA.

After Reconfiguration: switch 9 is in closed condition (sectionalized switch).

Load on feeder A is 7800 kVA, feeder B is 2000 kVA, feeder C is 8800 kVA and feeder D is 7300 kVA.

Case-3: Fault on feeder C is at position Z13

Because of fault, faulted section is separated by opening switches 23 and 24. Discarded load on feeder C is 2300 kVA.

Before Reconfiguration: load on feeder A is 6500 kVA, feeder B is 4300 kVA, feeder C is 6500 kVA and feeder D is 7300 kVA.

After Reconfiguration: switch 19,30 are in closed condition (tie switches),switch 35 open condition(i.e. Sectionalizing switch). Load on feeder A is 6500 kVA, feeder B is 6400 kVA, feeder C is 6500 kVA and feeder D is 6800 kVA.

Case-4: Fault on feeder C is at position Z14

Because of fault, faulted section is separated by opening switches 24 and 25. Discarded load on feeder C is 1600 kVA.

Before Reconfiguration: load on feeder A is 6500 kVA, feeder B is 4300 kVA, feeder C is7200 kVA and feeder D is 7300 kVA.

After Reconfiguration: switch 20 is in closed condition (sectionalized switch).Load on feeder A is 6500 kVA, feeder B is 4900 kVA, feeder C is 7200 kVA and feeder D is7300 kVA.

Case-5: Fault on feeder D at position Z17

Because of fault, faulted section is separated by opening switches 32 and 33. Discarded load on feeder B is 5800 kVA.

Before Reconfiguration: load on feeder A is 6500 kVA, feeder B is 4300 kVA, feeder C is 8800 kVA and feeder D is 1500 kVA.

After Reconfiguration: switches 10, 19, 29 are in closed condition(Sectionalized switches) and switches 15, 24 are in open condition (tie switches).Load on feeder A is 7800 kVA, feeder B is 2000 kVA, feeder C is 8800 kVA and feeder D is 7300 kVA.

4.2. Minimization of Ohmic Losses
4.2.1 IEEE 33 Bus Test System

The proposed technique was applied on IEEE 33 bus test system. The test system base voltage is 12.66kV,base MVA -100 and total system real and reactive loads are 3715kW and 2300kVAR, respectively, and it consists of five tie switches.

Before reconfiguration - Initial network configuration consists of S1 to S32 are the sectionalizing switches and S33 to S37 are the tie switches. For this combination real power, reactive power and apparent power losses are 202.6771kW, 135.1410 kVAR and 243.6 kVA respectively.

After reconfiguration - the optimal configuration obtained by the proposed algorithm is S29, S33, S34, S35, S37 are the tie switches (i.e. dotted lines) remaining all are the sectionalizing switches as shown in below Figure 6. For this combination real power, reactive power and apparent power losses are 109.6065kW, 78.0381 kVAR and 134.5494 kVA respectively. After (Optimal) reconfiguration, 45.9206 % of loss reduction is obtained comparatively.
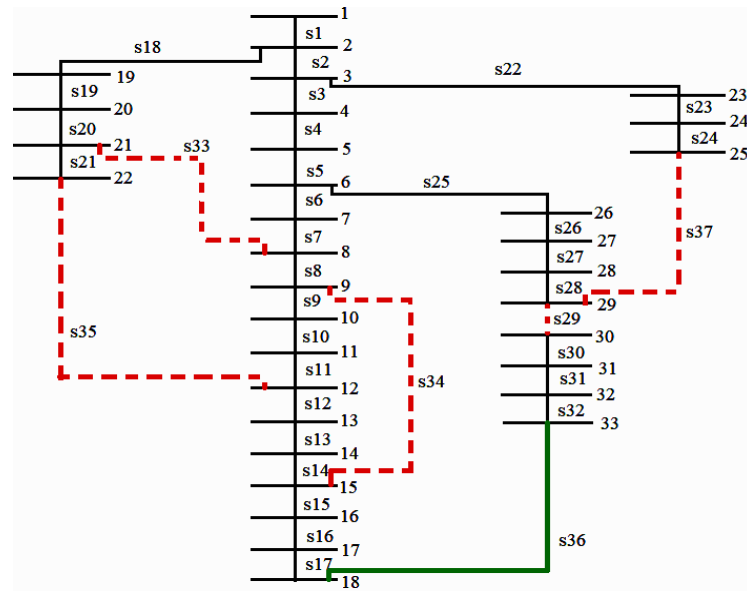

Figure 6. 33 Bus test system after reconfiguration

4.2.2 IEEE 69 Bus Test System

The proposed technique was applied on IEEE 69 bus test system. The test system base voltage is 12.66 kVA, base MVA-100 and total system real and reactive loads are 3802.19kW and 2694.6kVAR, respectively, and it consists of five tie switches.

Before reconfiguration-Initial network configuration consists of switches 1 to switch 68 are considered by the sectionalizing switches and switch 70 to switch 74 are the tie switches. For this combination real power, reactive power and apparent power losses are 225.0028kW, 102.1659 kVAR and 247.1116 kVA respectively.

After reconfiguration-switches 49, 64, 70, 71, 72 are the tie switches (i.e. dotted lines) remaining are the sectionalizing switches as shown in below Figure 7. For this combination real power, reactive power and apparent power losses are 71.1381kW, 78.7572 kVAR and 106.1288 kVA respectively. After (Optimal) reconfiguration, 68.3834 % of loss reduction is obtained comparatively.
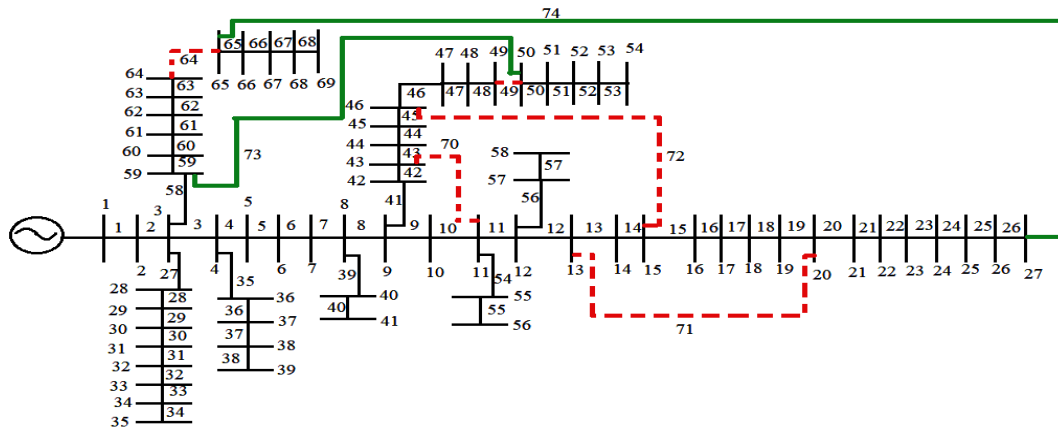
Figure 7. 69 bus test system after reconfiguration

5.   RESULTS
5.1.   IEEE Four Feeder Service Restoration
The simulation results of distribution system reconfiguration based on AACO for IEEE 4- feeder service restoration are shown in Table 2.

Table 2. Results of 4 Feeder System under Faulty Conditions at Different Locations

Feeder	Fault at	Optimal switching operation	LBI
A	Switch-1	Closed Switches - 6&20	0.200853
		Open Switch - 15	
B	Z8	Closed Switch - 9	0.131974
C	Z13	Closed Switches - 19&30	0.0075
		Open Switch - 35	
C	Z14	Closed Switch - 20	0.048007
D	Z17	Closed Switches - 10,19&29	0.140506
		Open Switches - 15&24	

In IEEE four feeder test system, for same fault on feeder-C at position Z13. Continuity of power supply maintained, optimal LBI value of proposed method is compared with other reference papers LBI values, among those proposed method gives least LBI value as shown in below Table 3.

Table 3. Results Validation of Four Feeder System for Service Restoration

Method	LBI value for the same fault on feeder-C at position Z13
Dr.P.Ravi Babu[22]	0.0100
Dr.P.Ravi Babu[23]	0.0124
Proposed method	0.0075

5.2.   Minimization of Ohmic Losses
In order to express the proposed method IEEE 33and 69 bus test systems are taken into consideration. The method is coded using MATLAB version R2017a is used to run the optimal power flow solver with direct load flow method. AACO is carried out best results, are shown in Table 4 and Table 5.

Table 4. Results Validation for 33 Bus Test System

Method	Tie Switches	Loss After Reconfiguration(kW)	%I^2R Loss Reduction
J.Z.Zhu [5]	S7,S9,S14,S32,S33	139.532	31.1555
Majid Jamil et al. [10]	S2,S13,S16,S33,S37	112.68	44.4041
Firas M.F.Flaih et al. [11]	S7,S9,S14, S32,S37	139.55	31.1466
proposed	S29,S33,S34,S35,S37	109.6065	45.9206

Table 5. Results Validation for 69 Bus Test System

Method	Tie Switches	Loss After Reconfiguration(kW)	%I^2R Loss Reduction
Inji Ibrahim atteya et al. [12]	14,55,61,69,70	100.6	55.2894
Soumitri Jena et al. [13]	12,18,58,61,69	103.62	53.9472
Tandon.A et al.[14]	13,20,55,61,69	107.05	52.4228
proposed	49,64,70,71,72	71.1381	68.3834

Improvement in Bus Voltages Before and After Reconfiguration of 33 Bus and 69 Bus Test Systems, as shown in Figure 8.
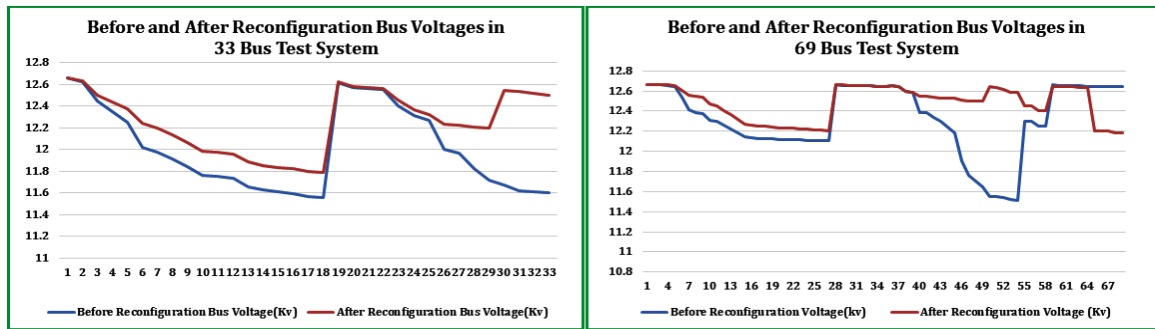

Figure 8. Bus voltages before and after reconfiguration of 33 bus and 69 bus test systems

6.   CONCLUSION

Service restoration and Ohmic loss minimization in distribution system are the main objectives in this paper. Service restoration achieved on IEEE 4-feeder test system under faulty conditions at different locations and for the same fault at Z13 on feeder-C least LBI value is obtained with proposed technique compared to other reference papers. The Ohmic losses are minimized optimally in IEEE 33 and IEEE 69 bus test systems with I^2 R loss reduction by 45.9206% and 68.3834% respectively. The minimum voltage before reconfiguration is 11.5597 kV at node-18 and after reconfiguration it is raised to 11.7876 kV at node-18 for 33 bus test system. The minimum voltage before reconfiguration is 11.5103 kV at node-54 and after reconfiguration it is raised to 12.181 kV at node-69 for 69 bus test system. These objectives achieved through reconfiguration by using artificial ant colony optimization (AACO).

REFERENCES

[1]   Civanlar, J. J. Grainger, H. Yin & S.S.H. Lee, "distribution feeder reconfiguration for loss reduction", *IEEE Trans. On power delivery*, vol.3, No.3, July 1988, pp.1217-1223.
[2]   Shirmohammadi and H.W.Hong, "reconfiguration of electric distribution networks for resistive line loss reduction", *IEEE Trans. on power apparatus and systems* Vol.4, No.2, 1989, pp.1492-1498.
[3]   M.E.Baran & F.Wu, "network reconfiguration in distribution systems for loss reduction &load balancing", *IEEE Trans. power Del*., 1989, 4(2), pp.1401-1407.
[4]   Taylor, D. Lubkeman, "implementation of heuristic strategies for distribution feeder reconfiguration", *IEEE Trans. on power Del*., Vol.5, No.1, Jan.1990, pp.239-245.
[5]   J.Z.Zhu, "optimal reconfiguration of electrical distribution network using refined genetic algorithm", *Electrical Power System Research*, vol.62, pp.3202, 2002.
[6]   Jorge Mendoza, Rodrigo Lopez et al., "minimum loss reconfiguration using genetic algorithms with restricted population & addressed operators: Real application", *IEEE*, 2006.
[7]   Dr. P Ravi Babu, K. Prapoorna et al., "multiobjective approach for feeder overloading and service restoration through reconfiguration", *IETECH*, 2007.
[8]   Dr. Ravi Babu, Sai Sushma et al., "a novel ACO based search approach to enhance the distribution system load balance", *ICIIECS*,2017.
[9]   F.S. Pereira, K. Vittori, G.R.M. da Costa, "ant colony based method for reconfiguration of power distribution system to reduce losses", *IEEE*, 2008.
[10] Majid Jamil, Amit Sharma, "ant colony optimization for restoration of distribution system", *IEEE*, 2015.
[11] Firas M.F.Flaih, Lin Xiangning et al, "distribution system reconfiguration for power loss minimization and voltage profile improvement using modified particle swarm optimization", 2016 IEEE PES.
[12] Inji Ibrahim atteya, Hamdy Ashour, "radial distribution network reconfiguration for power losses reduction using a modified particle swarm optimization", *CIRED*, 2017.

[13] Soumitri Jena, Sushil Chauhan, "solving distribution feeder reconfiguration and concurrent DG installation problems for power loss minimization by multi swarm cooperative PSO algorithm", *IEEE* 2016.

[14] Tandon. A, Saxena. D, "a comparative analysis of SPSO &BPSO for power loss minimization in distribution system using network reconfiguration", Proc. Int. Conf, *Innovative applications of computational intelligence on power energy &controls with their impact on humanity*, November-2014, pp.226-232.

[15] S.Ganesh, R, Kanimozhu, "an effective soft computing technique for network reconfiguration in distribution system", *ICACCCT*, 2016.

[16] Dusharla Venkata Sunil, Narri Yadaiah, "a novel improved particle swarm optimization frame work for reconfiguration of radial distribution system", *IEEE*, India, 2017.

[17] A.V. Sudhakara Reddy, M.Damodar Reddy, M.Satish Kumar Reddy, "network reconfiguration of distribution system for loss reduction using GWO algorithm", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol.7, No.6, December2017, pp.3226-3234.

[18] S. Surender Reddy, "optimal reactive power scheduling using cuckoo search algorithm", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol.7, No.5, October2017, pp.2349-2356.

[19] Lakshmi M, Ramesh Kumar A, "optimal reactive power dispatch using crow search algorithm", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol.8, No.3, June2018, pp.1423-1431.

[20] Surender Reddy Salkuti, "multi-objective based optimal energy and reactive power dispatch in deregulated electricity markets", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol.8, No.5, October2018, pp.3427-3435.

[21] Zeba Khan, Mahfooz Alam, Raza Abbas Haidri, "effective load balance scheduling schemes for heterogeneous distribution system", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol.7, No.5, October2017, pp.2757-2765.

[22] Dr.P.Ravi Babu, Sushma Pasunuru, Vaishnavi Gattu, "Solution of Multi Objective Problems for Weekly Meshed Distribution System through Genetic Algorithm", *International Conference on Recent Innovations in Electrical and Electronics Engineering*, JNTU, Hyderabad, India.

[23] Dr. Pallikonda Ravi Babu, K. Anish Kumar, G. Charan Teja, "New Heuristic Search Approach to Enhance the Distribution System Load Balance",2013 *International Conference on Power, Energy and Control(ICPEC)*.

[24] Deepti Yadav, Arunima Verma, "Comperative Performance Analysis of PMSM Drive Using MPSO and ACO Techniques", *International Journal of Power Electronics and Drive Systems (IJPEDS),* Vol.9, No.4, December 2018, pp.1510-1522.

[25] Gagari Deb, Kabir Chakraborty, "Gauss Seidel Method based Voltage Security Analysis of Distribution System", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol.8, No.1, February 2018, pp.43-51.

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