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ARTIFICIAL BEE COLONY ALGORITHM FOR DISTRIBUTION FEEDER RECONFIGURATION WITH DISTRIBUTED GENERATION

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ABSTRACT

Optimal reconfiguration involves selection of the best set of branches to be opened, one each from each loop, such that the resulting radial distribution system has the desired performance. This paper presents a feeder reconfiguration problem in the presence of distributed generation to minimize the system power loss and voltage profile improvement. Artificial bee colony algorithm (ABC) is proposed to reconfiguration of radial distribution system in the presence of distributed generation. Loss Sensitivity index is used to identify optimal location for installation of DG unit. Different cases of DG placement and reconfiguration of network are considered to study the performance of the proposed method. Simulation study is conducted on 33-bus radial test system at five different cases to verify the efficacy of the proposed method with existing method.

KEYWORDS: *distributed generation, artificial bee colony algorithm, distribution feeder reconfiguration, loss reduction, radial distribution network.*

I. INTRODUCTION

Distribution systems consist of groups of interconnected radial circuits. The configuration may be varied via switching operations to transfer loads among the feeders. Two types of switches are used in primary distribution systems. They are normally closed switches (sectionalizing switches) or normally open switches (tie switches). Both types are designed for both protection and configuration management. Network reconfiguration is the process of changing the topology of distribution systems by altering the open/closed status of switches.

Distribution systems are usually designed with an open ring and are operated in a radial manner. If all switches are closed, the network losses will be at the minimal level. However, due to the complexity of protective systems and the high rate of short circuits, this is not possible. In recent years, with the development of data processing technologies and their transfer, distribution companies are becoming fonder of automation distribution systems. One of the most effective applications of automation is the reconfiguration of distribution systems. Reconfiguration is actually turning the switches off and on in distribution systems for changing the network topology and thus changing it for power flow. Also the first and main purpose of reconfiguration is reducing losses in distribution systems and preventing network overload.

Network reconfiguration is used for loss reduction and voltage-profile improvement while the radial structure of distribution system is retained [1, 2].

Distributed generation, unlike traditional generation, aims to generate part of required electrical energy on small scale closer to the places of consumption and interchanges the electrical power with the network. It represents a change in the paradigm of electrical energy generation. The distributed generation, also termed as embedded generation or dispersed generation or decentralized generation, has been defined as electric power source connected directly to the distribution network or on the customer site of the meter [3]. The emergence of new technological alternatives allows the DG technologies in distribution network to achieve immense technical, economical and environmental benefits [4]. These benefits could be maximized by proper planning i.e. placement of DG at optimum location with optimum size and suitable type. The majority of the distributed generation planning objective was to minimize the real power loss in network.

One of the first papers on reconfiguration was presented by Merlin and Back [5]. Civanlar et al. introduced a simple innovative method for calculating the loss through the network reconfiguration [6]. Shirmohammadi and Hong presented the use of the power flow method based on a heuristic algorithm to determine the minimum loss configuration for radial distribution networks [7]. Baran andWu modeled the problem of loss reduction and load balancing as an integer programming problem [8]. Nara et al. have presented an implementation using a genetic algorithm to look for the minimum loss configuration [9]. Chiang and Rene proposed a solution procedure which used simulated annealing to search for an acceptable non inferior solution [10]. Goswami and Basu introduced a power-flow-minimum heuristic algorithm for distribution feeder reconfiguration [11]. Vanderson Gomes et al. proposed a heuristic strategy for reconfiguration of distribution systems [12].Lopez presented an approach for online reconfiguration [13]. Das proposed a fuzzy multi-objective approach to solve the network reconfiguration problem [14]. Niknam et al. presented an efficient hybrid algorithm for multi-objective distribution feeder reconfiguration based on Honey Bee Mating Optimization (HBMO) and fuzzy multi-objective approach [15].Olamaei et al. proposed a cost based on compensation methodology for distribution feeder reconfiguration considering distributed generators [16]. Niknam et al. presented an efficient multi-objective modified shuffled frog leaping algorithm that has been used to solve MDFR problem[17]. J. Olamaei et al. proposed a hybrid evolutionary algorithm based on ACO and SA for distribution feeder reconfiguration [18].R.S rao et al proposed a harmony search algorithm for distributor reconfiguration [19]. J. Olamaei et al. presented a modified honey bee mating optimization algorithm for distribution feeder reconfiguration for loss Minimization with distributed generations [20].

In this paper, an Artificial Bee Colony (ABC) algorithm is used to solve a 33- bus radial feeder reconfiguration with DG to reduce system loss in the distribution network. Minimizing the total system losses without violating operation constraints and maintaining the radial structure.

The rest of this paper is organized as follows: Section 2 gives the problem formulation, Section 3 gives the overview of proposed ABC algorithm, Section 4 presents simulation results, and Section 5 concludes this paper.

II. PROBLEM FORMULATION

In the radial distribution system, each radial feeder is divided into load sections with sectionalizing switches and is connected to other feeders via several tie switches. Due to the fact that reducing the real power loss of the distribution feeders is an important purpose in feeder reconfiguration, in the distribution feeder reconfiguration problem minimizing the real power loss of the feeders is considered as objective function. The total real power losses of the distribution network can be calculated as follows

$$P_L = min \sum_{k=1}^{n-1} R_k \left| I_k \right|^2 \tag{1}$$

Where

P_L is total system loss,

n is number of nodes in the distribution network,

R_k is resistance of k^{th} line,

$|I_k|$ is absolute of k^{th} line current, subject to the following.

i) Voltage constraint: voltage magnitude of each branch must lie within their permissible ranges to maintain power quality.
ii) Isolation constraint: all of nodes are energized.
iii) Radial network constraint: distribution networks should be composed of radial structure operation.

For placement of distributed generation, the loss sensitive factors [21] at different buses have been evaluated to select appropriate nodes for DG planning by using load flow program. These sensitivity factors reflect how the feeder power losses change and obtaining the candidate nodes to locate DG. Loss sensitive factors are evaluated for the base case first to decide the first appropriate location. Artificial bee colony algorithm (ABC) is used to obtain the solution for reconfiguration with DG of radial distribution system to minimize the losses.

III. ARTIFICIAL BEE COLONY ALGORITHM

Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Dervis Karaboga in 2005, motivated by the intelligent behavior of honeybees. ABC as an optimization tool provides a population based search procedure in which individuals called food positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar. In this algorithm [22, 23], the colony of artificial bees consists of three groups of bees: employed bees, onlookers and scouts. First half of the colony consists of the employed artificial bees and the second half includes the onlookers. For every food source, there is only one employed bee. In other words, the number of employed bees is equal to the number of food sources around the hive. The employed bee whose food source has been abandoned becomes a scout [24].

Thus, ABC system combines local search carried out by employed and onlooker bees, and global search managed by onlookers and scouts, attempting to balance exploration and exploitation process [25].

The ABC algorithm creates a randomly distributed initial population of solutions ($f = 1,2,\ldots,E_b$), where 'f' signifies the size of population and 'E_b' is the number of employed bees. Each solution x_f is a D-dimensional vector, where D is the number of parameters to be optimized. The position of a food-source, in the ABC algorithm, represents a possible solution to the optimization problem, and the nectar amount of a food source corresponds to the quality (fitness value) of the associated solution. After initialization, the population of the positions (solutions) is subjected to repeated cycles of the search processes for the employed, onlooker, and scout bees (cycle = 1, 2, …, MCN), where MCN is the maximum cycle number of the search process. Then, an employed bee modifies the position (solution) in her memory depending on the local information (visual information) and tests the nectar amount (fitness value) of the new position (modified solution). If the nectar amount of the new one is higher than that of the previous one, the bee memorizes the new position and forgets the old one. Otherwise, she keeps the position of the previous one in her memory. After all employed bees have completed the search process, they share the nectar information of the food sources and their position information with the onlooker bees waiting in the dance area. An onlooker bee evaluates the nectar information taken from all employed bees and chooses a food source with a probability related to its nectar amount. The same procedure of position modification and selection criterion used by the employed bees is applied to onlooker bees. The greedy-selection process is suitable for unconstrained optimization problems. The probability of selecting a food-source p_f by onlooker bees is calculated as follows:

$$P_i = \frac{fitness}{\sum_{f=1}^{E_b} fitness_f} \tag{2}$$

Where $fitness_f$ is the fitness value of a solution f, and E_b is the total number of food-source positions (solutions) or, in other words, half of the colony size. Clearly, resulting from using (2), a good food source (solution) will attract more onlooker bees than a bad one. Subsequent to onlookers selecting their preferred food-source, they produce a neighbor food-source position $f+1$ to the selected one f, and compare the nectar amount (fitness value) of that neighbor $f+1$ position with the old position. The same selection criterion used by the employed bees is applied to onlooker bees as well. This sequence is repeated until all onlookers are distributed. Furthermore, if a solution f does not improve for a specified number of times (limit), the employed bee associated with this solution abandons it, and she becomes a scout and searches for a new random food-source position. Once the new position is determined, another ABC algorithm (*MCN*) cycle starts. The same procedures are repeated until the stopping criteria are met.

In order to determine a neighboring food-source position (solution) to the old one in memory, the ABC algorithm alters one randomly chosen parameter and keeps the remaining parameters unchanged. In other words, by adding to the current chosen parameter value the product of the uniform variant [-1, 1] and the difference between the chosen parameter value and other "random" solution parameter value, the neighbor food-source position is created. The following expression verifies that:

$$x_{fg}^{new} = x_{fg}^{old} + u\left(x_{fg}^{old} - x_{mg}\right) \tag{3}$$

Where $m \neq 1$ and both are $\in \left\{1, 2, ..., E_b\right\}$. The multiplier u is a random number between [-1, 1] and $g \in \left\{1, 2, ..., D\right\}$. In other words, x_{fg} is the g^{th} parameter of a solution x_f that was selected to be modified. When the food-source position has been abandoned, the employed bee associated with it becomes a scout. The scout produces a completely new food-source position as follows:

$$x_{fg}^{(new)} = min\left(x_{fg}\right) + u\left[max\left(x_{fg}\right) - min\left(x_{fg}\right)\right] \tag{4}$$

Where (4) applies to all g parameters and u is a random number between [-1, 1]. If a parameter value produced using (3) and/or (4) exceeds its predetermined limit, the parameter can be set to an acceptable value. In this paper, the value of the parameter exceeding its limit is forced to the nearest (discrete) boundary limit value associated with it. Furthermore, the random multiplier number u is set to be between [0, 1] instead of [-1, 1]

The proposed ABC algorithm for finding size of DG at selected location to minimize the real power loss is as follows:

Step-1: Initialize the food-source positions x_f (solutions population), where $f = 1,2,.....,E_b$. The x_f solution form is as follows.

Step-2: Calculate the nectar amount of the population by means of their fitness values using

$$Fitness = \frac{1}{1 + powerloss} \tag{5}$$

Step-3: Produce neighbor solutions for the employed bees by using equation (3) and evaluate them as indicated by Step 2.

Step-4: Apply the selection process.

Step-5: If all onlooker bees are distributed, go to Step 9. Otherwise, go to the next step.

Step-6: Calculate the probability values P_f for the solutions x_f using equation (2)

Step-7: Produce neighbor solutions for the selected onlooker bee, depending on the value, using equation (3) and evaluate them as Step 2 indicates.

Step-8: Follow Step 4.

Step-9: Determine the abandoned solution for the scout bees, if it exists, and replace it with a completely new solution using equation (4) and evaluate them as indicated in Step 2.
Step-10: Memorize the best solution attained so far.
Step-11: If cycle = MCN, stop and print result. Otherwise follow Step 3.

IV. RESULTS AND ANALYSIS

The performance of the proposed method is evaluated on 33 bus radial distribution system [19] to minimize the power loss by network reconfiguration with distribution generation. The load data, line details and data of tie lines are given in appendix and Fig. 2 along with a single line diagram. The system consists of one source transformer, 32 bus-bars, and 5 tie switches. The total active and reactive power for the whole system loads are 3715 kW and 2300 kVAr, respectively. The initial statuses of all the sectionalizing switches (switches No. 1-32), which are indicated by solid lines are closed while all the tie-switches (switches No. 33-37) which are shown by dotted lines are open. The initial losses and minimum voltage are 202.665 kW and 0.9131 per unit for initial configuration, respectively. The Control parameters of ABC method are colony size (*Cs)* is 30 and *MCN* is 20. The simulation results are presents in Table 1 and the node voltages at each bus are shown in Table 2. Five cases are considered for the proposed method as follows, The case-1 results of the proposed method are compared with the harmony search algorithm [19] shown in Table 1. The percentage of loss reduction for various cases is shown in Fig.1.

Case-1: The feeder is reconfiguration without distributed generation

The optimal configuration obtained by the proposed method is 7, 14, 31, 35 and 37, which has a real power loss of 122.1357 kW. This amounts to a reduction of 39.73% in total power loss. Before reconfiguration, the minimum bus voltage is 0.9131 p.u. and the minimum bus voltage of the system is improved to 0.9319 p.u after reconfiguration. The average voltage of the system is 0.9704 p.u. From the Table 2, it is observed that the optimal power loss obtained by the proposed method is less than the existing method [19].

Case-2: The feeder is distributed generation and without reconfiguration

The optimum size of DG at bus 6 is 2520.5 kW. The improvement of minimum bus voltage of system after optimally placing the DG by proposed method is 0.9568 p.u. The average voltage of the system is 0.9788 p.u after installing DG. Similarly the losses have reduced to 103.3509 kW. This amounts to a reduction of 49% in total power loss.

Case-3: The feeder is distributed generation with reconfiguration

The same as case 2 except that there is feeder reconfiguration, the optimum size of DG at bus 6 is 2520.5 kW. The optimal configuration is 7, 14, 31, 35 and 37, which has a real power loss of 94.9593 kW. This amounts to a reduction of 53.14% in total power loss. The minimum bus voltage of the system is 0.9566 p.u and the average voltage of the system is 0.9853 p.u.

Case-4: The feeder is reconfiguration and distributed generation placement

The same as case 1 except that there is a DG, the optimum size of DG at bus 22 is 817.07 kW. The optimal configuration is 7, 14, 31, 35 and 37, which has a real power loss of 88.0816 kW. This amounts to a reduction of 56.53% in total power loss. The minimum bus voltage of the system is 0.9507 p.u and the average voltage of the system is 0.9805 p.u.

Table 1: Results of cases study.

Description		**Case 1**		**Case 2**	**Case 3**	**Case 4**	**Case 5**
		Existing method [19]	**Proposed method**	**Proposed method**			
DG	Location	—		6	6	15	15

placement	Size (kW)			2520.5	2520.5	817.07	960.23
Open switches		7,10,14 37,36	7,14,31, 35,37	33,34,35, 36,37	7,14,31, 35,37	7,14,31, 35,37	7,9,31, 35,37
Average voltage (p.u.)		0.9659	0.9704	0.9788	0.9853	0.9805	0.9879
Total real power loss (kW)		138.06	122.1357	103.3509	94.9593	88.0816	63.22
Loss reduction (%)		31.89	39.73	49.00	53.14	56.53	68.8

Case-5: simultaneous solution of feeder reconfiguration and DG placement

The simultaneous solution of the optimal reconfiguration and DG setting problem determines which network switches should be open and closed as well as DG size in order to reduce losses and improve voltage profile. The optimum size of DG at bus 22 is 960.23 kW. The average voltage of the system is 0.9879 p.u and minimum voltage is improved to 0.9740 p.u. after simultaneous solution of feeder reconfiguration and DG placement. Similarly the losses have reduced to 63.22 kW. This amounts to a reduction of 68.8% in total power loss.

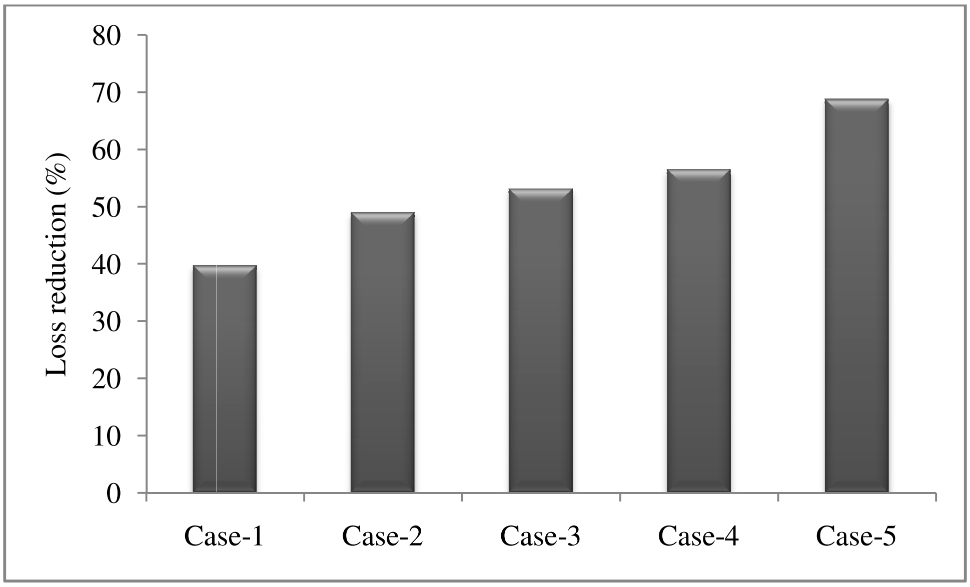

Fig 1: Loss reduction for 33-bus radial distribution system.

Table 2: Bus voltages of 33-bus system

Bus number	Case 1		Case 2	Case 3	Case 4	Case 5
	Existing method [19]	Proposed method	Proposed method			
1	1.000	1.000	1.000	1.000	1.000	1.000
2	0.9971	0.9971	0.9988	0.9986	0.9976	0.9982
3	0.9869	0.988	0.9943	0.9965	0.9885	0.9921
4	0.9823	0.9841	0.9940	0.9979	0.9846	0.9905
5	0.9778	0.9805	0.9940	0.9998	0.9810	0.9893
6	0.9666	0.9713	0.9917	1.0023	0.9718	0.9853
7	0.9659	0.9707	0.9884	1.0017	0.9712	0.9846
8	0.9653	0.9613	0.9838	0.9826	0.9842	0.9887

9	0.9621	0.9559	0.9778	0.9717	0.9844	0.9899
10	0.9616	0.9955	0.9722	0.9970	0.9960	0.9959
11	0.9681	0.9947	0.9714	0.9962	0.9952	0.9960
12	0.9683	0.9951	0.9700	0.9966	0.9956	0.9948
13	0.9657	0.9949	0.9641	0.9964	0.9954	0.9956
14	0.9649	0.9945	0.9620	0.9960	0.9950	0.9963
15	0.9574	0.9456	0.9606	0.9684	0.9850	0.9922
16	0.9561	0.9424	0.9593	0.9624	0.9819	0.9892
17	0.9541	0.9365	0.9574	0.9606	0.9762	0.9835
18	0.9536	0.9341	0.9568	0.9577	0.9739	0.9812
19	0.9953	0.9954	0.9983	0.9832	0.9968	0.9975
20	0.9802	0.9806	0.9947	0.9972	0.9902	0.9924
21	0.9760	0.9766	0.9940	0.9856	0.9885	0.9911
22	0.9733	0.9759	0.9934	0.9819	0.9879	0.9905
23	0.9833	0.9844	0.9908	0.9739	0.9849	0.9886
24	0.9767	0.9777	0.9842	0.9930	0.9783	0.9820
25	0.9734	0.9744	0.9809	0.9864	0.9749	0.9787
26	0.9647	0.9699	0.9899	1.0006	0.9704	0.9851
27	0.9622	0.9681	0.9874	0.9983	0.9686	0.9850
28	0.9510	0.9597	0.9765	0.9882	0.9602	0.9834
29	0.9429	0.9538	0.9687	0.9809	0.9544	0.9776
30	0.9395	0.9515	0.9653	0.9778	0.9521	0.9754
31	0.9354	0.9501	0.9613	0.9745	0.9507	0.9740
32	0.9345	0.9319	0.9604	0.9566	0.9717	0.9791
33	0.9342	0.9327	0.9601	0.9567	0.9725	0.9799

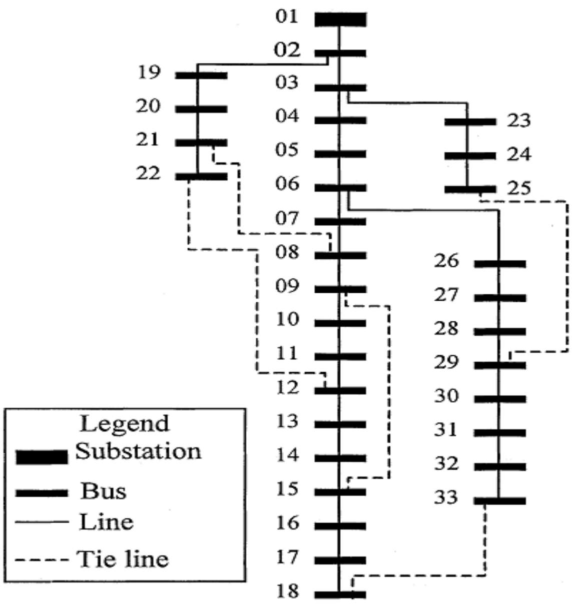

Fig 2: The 33-bus radial distribution system.

V. CONCLUSIONS

In this paper, Artificial Bee Colony (ABC) algorithm is proposed to solve distribution feeder reconfiguration with distributed generation (DG) for 33 bus system. Although the optimal on/off patterns of the switches contributes to loss reduction and voltage profile improvement. It can be observed that 68.8% of loss reduction and average voltage of 0.9879 p.u. can be achieved by the case 5 is the simultaneous solution of feeder reconfiguration and DG placement comparing with other cases by the ABC method in the system. The results show that the artificial bee colony algorithm for real power loss minimization to be the most effective and efficient.

REFERENCES

[1]. Baran, M .E. and Wu, F.F, "Network reconfiguration in distribution systems for loss reduction and load balancing," IEEE Trans. Power Deliv., 1989, Vol. 4, No. 2, pp. 1401–1407.

[2]. Kashem, M.A., Ganapathy, V. and Jasman, G.B. "Network reconfiguration for enhanceme nt of voltage stability in distribution networks," IEE Proc. C-Genes. Transm. Distrib., 2000, pp. 171 –175.

[3]. Ackermann T., Andersson G., Soder L., "Distributed generation: a definition," Electric Power Systems Research, 2001, Vol. 57, no.3 pp. 195–204.

[4]. Chiradejaand P., and Ramakumar R ., "An approach to quantify the technical benefits of distributed generation," IEEE Trans. Energy Convers., 2004, Vol.19, no .4, pp. 764–773.

[5]. Merlin, A. and H. Back, "Search for a minimal-loss operating spanning tree configuration in an urban power distribution system," Proc. 5th Power System Computation Conf.,1975, Cambridge (U.K.): pp. 1-18.

[6]. Civanlar, S., J.J. Grainger, H. Yin and S.S.H. Lee, "Distribution feeder reconfiguration for loss reduction," IEEE Transactions on Power Delivery, 1988, No 3: pp. 1217-1223.

[7]. Shirmohammadi, D. and H.W. Hong, "Reconfiguration of electric distribution networks for resistive line loss reduction," IEEE Tran sactions on Power Systems, 1989, Vol.4: pp. 1492-1498.

[8]. Baran, M.E. and F.F. Wu, "Network reconfiguration in distribution systems for loss reduction and load balancing". IEEE Transactions on Power Delivery," 1989, Vol.4, pp.1401-1407.

[9]. Nara, K., A. Shiose, M. Kitagawoa and T. Ishihara, "Implementation of genetic algorithm for distribution systems loss minimum reconfiguration," IEEE Trans. Power Syst.,1992, Vol.7, pp.1044-1051.

[10]. Chiang, H.D. and J.J. Rene, "Optimal network reconfiguration in distribution systems:Part 2: Solution algorithms and numerical results," IEEE Trans Power Delivery, 1990, Vol.5, pp.1568-74.

[11]. Goswami, S.K. and S.K. Basu, "A new algorithm for the reconfiguration of distribution feeders for loss minimization," IEEE Transactions on Power Delivery, 1992, Vol.7, pp.1484-1491.

[12]. Vanderson Gomes, F., S. Carneiro, J.L.R. Pereira, Garcia Mpvpan, and L. Ramos Araujo "A new heuristic reconfiguration algorithm for large distribution systems," IEEE Transactions on Power systems, 2005, Vol.20, pp.1373-1378.

[13]. Lopez, E.h., "Opaso Online reconfiguration considering variability demand: Applications to real networks," IEEE Transactions on Power Systems, 2004, Vol.19, pp. 549-553.

[14]. Das, D., "A fuzzy multi-objective approaches for network reconfiguration of distribution systems," IEEE Transactions on Power Delivery, 2006, 21(1): 202-209.

[15]. Niknam, T., J. Olamaie and R. Khorshidi, "A Hybrid Algorithm Based on HBMO and Fuzzy Set for Multi-Objective Distribution Feeder Reconfiguration," Science China Technological Science, 2008, Vol.4, pp. 308-315.

[16]. Olamaei, J., T. Niknam and G. Gharehpetian, "An approach based on ant colony optimization for distribution feeder reconfiguration considering distributed generators," 19th International Conference on Electricity Distribution, Vienna, 2007.

[17]. Niknam, T., and E. Azad Farsani, "A hybrid self-adaptive particle swarm optimization and modified shuffled frog leaping algorithm for distribution feeder reconfiguration," Engineering Applications of Artificial Intelligence., 2010.

[18]. Olamaei, J., T. A. Arefi, A. H. Mazinan and Niknam, T, "A Hybrid Evolutionary Algorithm Base d on ACO and SA for Distribution Feeder Reconfiguration,"IEEE Computer and 2nd International Conference automation Engineering (ICCAE), 2010

[19]. R.S Rao, S.V.L Narasimham, M.R Raju and A.S Rao, "Optimal network reconfiguration of large scale distribution system using harmony search algorithem," IEEE transactions on power systems,2011, Vol.26 ,No.3, pp.1080-1088.

[20]. Javad Olamaei, Sirous badali and Taher Niknam, "Distribution Feeder Reconfiguration for Loss Minimization Based on Modified Honey Bee Mating Optimization Algorithm with Distributed Generations," Australian Journal of Basic and Applied Sciences, 2012, Vol.6, pp.133-141.

[21]. T. N. Shukla, S.P. Singh and K. B. Naik "Allocation of optimal distributed generation using GA for minimum system losses in radial distribution networks," International Journal of Engineering, Science and Technology, 2010, Vol. 2, No. 3, pp. 94-106.

[22]. Dervis Karaboga and Bahriye Basturk, "Artificial Bee Colony (ABC) Optimization Algorithm for Solving Constrained Optimization Problems," Springer-Verlag, IFSA 2007, LNAI 4529, pp. 789–798.

[23]. Karaboga, D. and Basturk, B., "On the performance of artificial bee colony (ABC) algorithm," *Elsevier Applied Soft Computing*, 2007, Vol. 8, pp.687–697.

[24]. S.Hemamalini and Sishaj P Simon., "Economic load dispatch with valve-point effect using artificial bee colony algorithm," xxxii national systems conference, NSC 2008.

[25]. Fahad S. Abu-Mouti and M. E. El-Hawary "Optimal Distributed Generation Allocation and Sizing in Distribution Systems via artificial bee Colony algorithm," IEEE transactions on power delivery, October 2011, Vol. 26, No. 4.

APPENDIX

Table 3: Data for 33-bus test system [19]

Line number	Sending end	Receiving end	Resistance (Ω)	Reactance (Ω)	Load at receiving end bus	
					Real power (kW)	Reactive power (kVAr)
1	1	2	0.0922	0.0470	100	60
2	2	3	0.4930	0.2511	90	40
3	3	4	0.3660	0.1864	120	80
4	4	5	0.3811	0.1941	60	30
5	5	6	0.8190	0.7070	60	20
6	6	7	0.1872	0.6188	200	100
7	7	8	0.7114	0.2351	200	100
8	8	9	1.0300	0.7400	60	20
9	9	10	1.0440	0.7400	60	20
10	10	11	0.1966	0.0650	45	30
11	11	12	0.3744	0.1238	60	35
12	12	13	1.4680	1.1550	60	35
13	13	14	0.5416	0.7129	120	80
14	14	15	0.5910	0.5260	60	10
15	15	16	0.7463	0.5450	60	20
16	16	17	1.2890	1.7210	60	20
17	17	18	0.7320	0.5740	90	40
18	2	19	0.1640	0.1565	90	40
19	19	20	1.5042	1.3554	90	40
20	20	21	0.4095	0.4784	90	40
21	21	22	0.7089	0.9373	90	40
22	3	23	0.4512	0.3083	90	50

23	23	24	0.8980	0.7091	420	200
24	24	25	0.8960	0.7011	420	200
25	6	26	0.2030	0.1034	60	25
26	26	27	0.2842	0.1447	60	25
27	27	28	1.0590	0.9337	60	20
28	28	29	0.8042	0.7006	120	70
29	29	30	0.5075	0.2585	200	600
30	30	31	0.9744	0.9630	150	70
31	31	32	0.3105	0.3619	210	100
32	32	33	0.3410	0.5302	60	40
33*	21	8	2.0000	2.0000		
34*	9	15	2.0000	2.0000		
35*	12	22	2.0000	2.0000		
36*	18	33	0.5000	0.5000		
37*	25	29	0.5000	0.5000		
*Tie switches, Substation voltage = 12.66 kV						

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