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Distribution Feeder Reconfiguration for Loss Minimization Based on Modified Honey Bee Mating Optimization Algorithm with Distributed Generations

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Abstract: This paper presents an efficient algorithm for multi-objective distribution feeder reconfiguration with distributed generation (DGs) based on Modified Honey Bee Mating Optimization (MHBMO) approach. The main objective of the Distribution feeder reconfiguration (DFR) is to minimize the real power loss, deviation of the nodes' voltage. Because of the fact that the objectives are different and no commensurable, it is difficult to solve the problem by conventional approaches that may optimize a single objective. So the metahuristic algorithm has been applied to this problem. This paper describes the full algorithm to Objective functions paid, The results of simulations on a 32 bus distribution system with DGs is given and Shown that the presence of DGs can reduce network losses more .As well as high accuracy and speed of the algorithm is demonstrated.

Key words: Distribution feeder reconfiguration (DFR), Distributed Generation (DG), Modified Honey Bee Mating Optimization (MHBMO), multi-objectives distribution feeder reconfiguration (MDFR).

INTRODUCTION

Distribution systems usually open ring design and operation as are radial. If all keys are closed, the network losses will be minimal. But due to the complexity and high level of protection short circuit if it does not work. In these systems there are two types of switches; sectionalizing-switches (normally closed) and tie-switches (normally open).The configuration of the distribution system is changed by opening sectionalizing switches and closing tie switches so that the radial structure of the network is maintained and all of the loads are supported, and reduced power losses and improve power quality and increase system security.Distribution feeder reconfiguration (DFR) is a complex nonlinear combinatorial problem since the status of the switches is non-differentiable. Therefore, most of the algorithms in the literature are based on heuristic search techniques, which use either analytical or knowledge-based engines. Generally, DFR is defined as altering the topological structure of the distribution feeders by changing the open/close states of sectionalizing and tie switches so that the objective function is minimized and the constraints are met .One of the first papers on this topic was presented by Merlin and Back (Merlin A, Back H., 1975). Civanlar et al. introduced a simple innovative method for calculating the loss through the network reconfiguration (Civanlar S, Grainger JJ, and Yin. H, Lee SSH, 1988). 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 (Shirmohammadi D, Hong HW.1989, Zhou Q, Shirmohammadi D, Liu WHE.,1997). Baran andWu modeled the problem of loss reduction and load balancing as an integer programming problem (Baran ME, Wu FF., 1989). Nara et al. have presented an implementation using a genetic algorithm to look for the minimum loss configuration (Nara, K., A. Shiose, M. Kitagawoa and T. Ishihara,1992). Chiang and Rene proposed a solution procedure which used simulated annealing to search for an acceptable non inferior solution (Chiang HD, Rene JJ.,1990). Goswami and Basu introduced a power-flow-minimum heuristic algorithm for distribution feeder reconfiguration (Goswami SK, Basu SK., 1992). Vanderson Gomes et al. proposed a heuristic strategy for reconfiguration of distribution systems (Vanderson Gomes F, Carneiro S, Pereira JLR, Garcia Mpvpan, Ramos Araujo L.,2005). Lopez presented an approach for online reconfiguration (Lopez E. h., 2004). Das proposed a fuzzy multi-objective approach to solve the network reconfiguration problem (Das D., 2006). 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 (Niknam T, Olamaie J, Khorshidi R., 2008). Olamaei et al. proposed a cost based on compensation methodology for distribution feeder reconfiguration considering distributed generators (Olamaei J, Niknam T, Gharehpetian G., 2007-2008). Niknam et al. presented an efficient multi-objective modified shuffled frog leaping algorithm that has been used to solve MDFR problem(Taher Niknam, Ehsan Azad farsani and Majid Nayeripour.,2010).

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The present work considers the network reconfiguration problem as a multi-objectives distribution feeder reconfiguration (MDFR), problem subject to operational and electric constraints. The problem formulation proposed here in considers two different objectives related to:

- Minimizing of the power losses
- Minimizing the deviation of the bus voltage

Problem Formulation:

This section proposes two objective functions for the network reconfiguration problem (Niknam,2009):

Objective functions:

As mentioned before, the proposed DFR problem has the following objectives:

Minimization of the power losses:

The minimization of the total real power losses arising from feeders can be calculated as follows:

$$f_1(x) = \sum_{i=1}^{N_{br}} R_i \times \left|I_i\right|^2$$

$$X = \left[Tie_1, Tie_2, ..., Tie_{N_{tie}}, Sw_1, Sw_2, ..., Sw_{N_{tie}}\right]$$

where *Ri* and *Ii* are resistance and actual current of the i^{ih} branch, respectively. *Nbr* is the number of the branches. X is the control variables vector. *Tiei* is the state of the i^{ih} tie switch (0 = open and 1=close). *Swi* is the sectionalizing switch number that forms a loop with *Tiei. Ntie* is the number of the tie switches.

Minimizing the deviation of the bus voltage:

Bus voltage is one the most significant security and service quality indices, which can be described as follows:

$$f_2(x) = \max_i \left|V_i - V_{rate}\right|, i = 1,2,3,...., N_{bus}$$

where *Nbus* is total number of the buses. V_i and V_{rate} are the real and rated voltages on the i^{ih} bus, respectively.

Original Hbmo Algorithm:

The honey bee is a social insect that can survive only as a member of a community, or colony. The colony inhabits an enclosed cavity. A honey-bee colony typically consists of a single egg laying long-lived queen, anywhere from zero to several thousand drones (depending on the season) and usually 10,000 to 60,000 workers. Queens are specialized in egg laying. Only the queen bee is fed ''royal jelly,'' which is a milky-white colored, jelly-like substance ''Nurse bees'' secrete this nourishing food from their glands, and feed it to their queen.A queen bee may live up to 5 or 6years, whereas worker bees and drones never live more than 6 months. There usually several hundred drones that live with the queen and worker bees. Drones are the fathers of the colony. They are haploid and act to amplify their mothers' genome without altering their genetic composition, except through mutation. Workers specialized in brood care and sometimes lay eggs. In the marriage process, the queen(s) mate during their mating flights far from the nest. A mating flight starts with a dance performed by the queen who then starts a mating flight during which the drones follow the queen and mate with her in the air. In each mating, sperm reaches the sperm theca and accumulates there to form the genetic pool of the colony. Each time a queen lays fertilized eggs, she randomly retrieves a mixture of the sperm cumulated in the sperm theca to fertilize the egg. At the start of the flight, the queen initialized with some energy content and returns to her nest when the energy is within some threshold from zero to full sperm theca (Omid B.,Abbas A, and Miguel A. 2006) .

The HBMO Algorithm combines a number of different procedures (Afshar, A., O. Bozog Haddad, M.A. Marino and B.J. Adams, 2007). Each of them corresponds to a different phase of the mating process of the honey bee. A drone mates with a queen probabilistically using an annealing function as follows:

$$\Pr ob(D) = \exp(-\Delta(f)/S(t))$$

where *Prob(D)* is the probability of adding the sperm of drone *D* to the sperm theca of the queen, $\Delta(f)$ is the absolute difference between the fitness of *D* and the fitness of the queen and *S(t)* is the speed of the queen at time t.

It is apparent that this function acts as an annealing function, where the probability of mating is high when either the queen is still in the start of her mating–flight and therefore her speed is high, or when the fitness of the drone is as good as the queen's.

After each transition in space, the queen's speed, $S(t)$, and energy, $E(t)$, decay using the following equations:

$$S(t+1) = \alpha \times S(t) \quad , \quad E(t+1) = E(t) - \gamma$$

where □ is a factor □(0,1) and is the amount of speed and energy reduction after each transition and each step. Initially, the speed of the queen is generated at random. A number of mating flights are realized.

Thus, an Honey-Bees Mating Optimization (HBMO) algorithm may be constructed with the following five main stages:

1. The algorithm starts with the mating–flight, where a queen (best solution) selects drones probabilistically to form the spermatheca (list of drones). A drone is then selected from the list at random for the creation of broods.
2. Creation of new broods (trial solutions) by crossover ring the drones' genotypes with the queen's.
3. Use of workers (heuristics) to conduct local search on broods (trial solutions).
4. Adaptation of workers' fitness based on the amount of improvement achieved on broods.
5. Replacement of weaker queens by fitter broods.

The main steps of the HBMO algorithm presented in Fig.1:

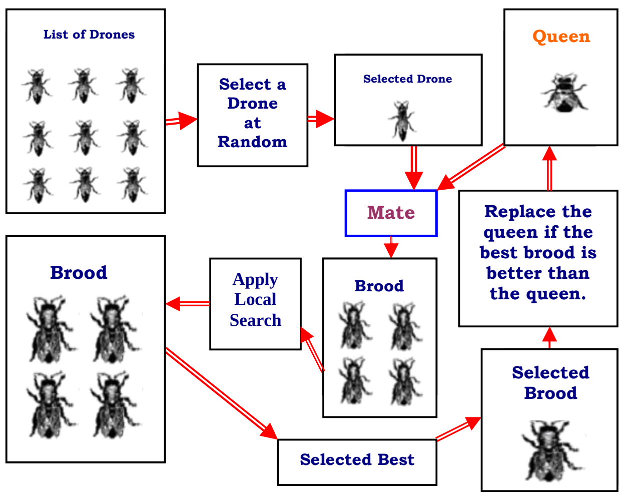

Fig. 1: The HBMO algorithm

Solution Of Mult-Objective Distribution Feeder Reconfiguration:

To apply the proposed algorithm in the distribution feeder reconfiguration problem, the following steps have to be taken:

Step 1: Define the input data:

In this step, the input data including the network configuration, line impedance and status of switches, the speed of queen at the start of a mating flight (*Smax*), the speed of queen at the end of a mating flight (*Smin*), the speed reduction schema (□), the number of iteration, the number of workers (*NWorker*), the number of drones (*NDreone*), the size of the queen's sperm theca (*NSperm*) and the number of broods (*NBrood*) are defined.

Step 2: Transfer the constraint optimization problem to an unconstraint one.

Step 3: Generate an initial population:

In this step, an initial population based on state variable is generated, randomly. That is formulated as:

$$Drone = \left[X_1 X_2 \ldots X_{N_{Drone}} \right]$$

$$X = \left[Tie_1, Tie_2, \ldots, Tie_{N_{tie}} \right] \; = 1,2,3,\ldots, N_{Drone}$$

Step 4: Calculate the objective function value by using results of the distribution load flow.
Step 5: Sort the initial population based on the objective function values.
Step 6: Select the queen:

The individual *(Xbest)* that has the maximum objective function should be considered as the queen.

Step 7: Generate the queen speed:

The queen speed is randomly generated as:

$$S_{queen} = rand\,(.) \times (S_{\max} - S_{\min}) + S_{\min}$$

where *rand(.)* is a random function generator.

Step 8: Select the population of the drones:

The population of drones is selected from the sorted initial population as:

$$Drone\_Population = \begin{bmatrix} D1 \\ D2 \\ D\,N_{Drone} \end{bmatrix}$$

$$D_i = \left[Tie_1, Tie_2, ..., Tie_{N_{tie}}, Sw_1, Sw_2, ..., Sw_{N_{tie}}\right]$$

$$i = 1, 2, 3, ..., N_{Drone}$$

Where D_i is the i^{th} drone.

Step 9: Generate the queen's sperm theca matrix (Mating flight):

At the start of the mating flight, the queen flies with her maximum speed. A drone is randomly selected from the population of drones. The mating probability is calculated based on the objective function values of the queen and the selected drone. A number between 0 and 1 is randomly generated and compared with the calculated probability. If it is less than the calculated probability, the drone's sperm is sorted in the queen's sperm theca and the queen speed is decreased. Otherwise, the queen speed is decreased and another drone from the population of drones is selected until the speed of the queen reaches to her minimum speed or the queen's sperm theca is full:

$$Spermacthe\ ca\_matrix = \begin{bmatrix} Sp_1 \\ Sp_2 \\ ... \\ Sp\,N_{Sperm} \end{bmatrix}$$

$$Sp_i = \left[s_j\right]_{1\times n} = \left[Tie_1, Tie_2, ..., Tie_{N_{tie}}, Sw_1, Sw_2, ..., Sw_{N_{tie}}\right]$$

$$i = 1, 2, 3, ..., N_{Sperm}$$

where *Spi* is the i^{th} individual in the queen's sperm theca.

Step 10: Breeding process:

In this step, a population of broods is generated based on mating between the queen and the drones stored in the queen's sperm theca. The i^{th} individual is generated as:

$$\overline{X}_{best} = \left[x_{best}^1\ x_{best}^2\ ....x_{best}^n\right]$$

$$Sp_i = \left[s_i^1 s_i^2 ... s_i^n\right]$$

$$Brood_j = round\,.\left(\overline{X}_{best} + \beta\left(\overline{X}_{best} - Sp_i\right)\right) j = 1,2,3,..., N_{Brood}$$

where β is a random number between 0 and 1. Broodj is the j^{th} brood.

Step 11: Feeding selected broods and queen with the royal jelly by workers:

The population of broods is improved by applying different heuristic functions and mutation operators as follows:

At first the i^{th} brood is randomly selected. Two integer numbers (*B1* and *B2*) between 1 and *n* are randomly generated. It is assumed *B1 < B2*. The brood is changed and improved as below:

$$Brood_i(j) = Brood_i(j) \quad if \quad j < B1$$

$$Brood_i(j) = rand(.) \times \left(x^j_{\max} - x^j_{\min}\right) + x^j_{\min}\,,$$
$$if \quad B1 \le J \le B2$$

$$Brood_i(j) = Brood_i(j) \quad if \quad j > B2$$

$$i = 1,2,3,....,N_{Worker}$$

where $x^j_{\max}$ and $x^j_{\min}$ are the maximum and minimum values of the jth state variables, respectively.

Step 12: Calculate the objective function value for the new generated solutions.
Step 13: Check the termination criteria:

If the termination criteria satisfied finish the algorithm, else discard all previous trial solutions and go to step 3 until convergence criteria met**.**

Modified Honey Bee Mating Optimization (Mhbmo) Algorithm:

The improvement process starts when the reproduction process is completed and offspring (i.e. broods) are generated. In this stage, different heuristic workers will selectively be activated to improve fitness of the generated offspring (i.e. broods' feeding). Heuristic functions are ranked according to their efficient contribution in solution improvements at each generation. Heuristic functions with a higher contribution in solution improvement will be used more extensively in the next improvement process. This feature will limit the unnecessary objective function evaluation for heuristic functions with non-significant contribution in solution improvements. The main difference between HBMO and MHBMO has been listed in Table (1).

Table1: Differences between the original and Modified HBMO algorithms

ID	Definition	HBMO	Modified HBMO
1	Improvement of the best solution (Queen feeding).	There is not a certain step for queen feeding after generating the population and selecting the best solution as Queen.	Queen feeding has been added after its generation by using some heuristic functions as workers.
2	Temperature (Queen's speed) reduction factor (α).	Constant factor e (0,1).	Linear factor with initial value of 1 and linear reduction till zero. Technically, this reduction factor (α) is the number of successful parent nominations (mating flight and adding a drone's sperm into sperm theca) over the size of mating pool (sperm theca).
3	Crossover (breeding) and mutation (broods feeding).	These two steps are done by using the crossover and mutation functions simultaneously.	Breeding would be done first using crossover functions and afterwards mutation functions are applied for broods feeding.
4	Heuristic functions (workers) Application.	6 heuristic functions are used for local search (broods feeding).	Number and type of heuristic functions are improved. The best scheme is selected after conducting sensitivity analysis.
5	Heuristic functions (workers) Updating.	Allocated space to heuristic functions in updating process is determined based on functions ranking. Considering multipliers of 10. Apparently , the better function quality , the more allocated space.	These allocated spaces from the population (hive) are determined relatively based on the amount of improvement which is produced by heuristic functions.

Simulation and Results:

The Baran and Wu distribution test system with 9 distributed generations (DGs),(The amount and type of DGs is shown in Table2), is a hypothetical 12.66 kV system with a two-feeder substation, 32 buses, and 5 looping branches. The number of ties and sectionalizing switches are 5 and 32, respectively. The system data is given in (Baran ME, Wu FF., 1989) and the single line diagram of this system is shown in Fig. 2. The total load conditions are 5058.25 kW and 2547.32 kVar. The normally open switches, s33, s34, s35, s36 and s37, are illustrated by doted lines. The normally closed switches, s1 to s32, are represented by solid lines. Before reconfiguration, the initial losses and minimum per unit voltage are 202.67 kW and 0.913p.u ,respectively,(without DGs and Sbase=100kva).

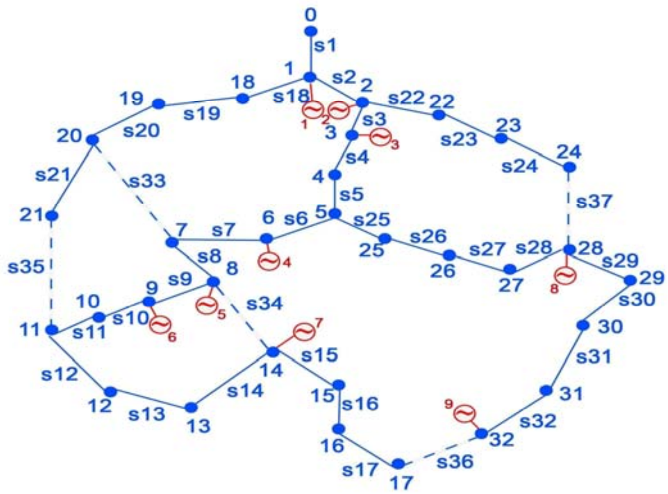

Fig. 2: A single line diagram of Baran and Wu distribution test system with DGs.

Table 2: DGs used and characteristics on the network

	No ofDG	busNo	P(kW)	Q(kW)
DGs=	1	1	10	2
	2	2	3	3
	3	3	6	2
	4	6	2	3
	5	8	9	2
	6	9	1	2
	7	14	8	3
	8	28	4	2
	9	32	3	3

At first, total real power losses, the number of switching operations and the voltage deviation of the buses are separately optimized to find the extreme points of the trade-off front. The best results obtained by optimizing the first and the Second objectives separately are shown in Tables (3) and (4), respectively. The results shown change in the status of the tie and sectionalizing switches. In Table (3) the best results obtained by optimizing the first objective of the proposed algorithm have been shown. From Table (4), it is obvious that the solution obtained by the proposed algorithm is better than the others. In Table (4) the best results obtained by optimizing the first objective of the proposed algorithm are compared with other studies. As shown in the Tables (3) and(4), the algorithm is capable of finding the best solutions for each objective function in real power loss minimization. According to Tables (3) and (4), the best solutions obtained by minimizing real power losses and voltage deviation separately are not the same, hence despite saying these objective are not different; in these tables (Tables 3 and 4) it has been shown that in some solutions these objectives are not commensurable. Also in most references, ‘‘Deviation of the node’s voltage’’ and ‘‘real power loss’’ are considered as two objective functions.

Table 3: Results obtained by optimizing the total real power losses

Method	Power losses (Kw)	Loss reduction (%)	Minimum voltage (p.u)	Open switches
Optimum (Vanderson, Carneiro, Pereira, Garcia, Ramos.,2005)	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
Goswami SK, Basu SK.,1992	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
Ching-Tzong Su., Chu-sheng Lee.,2003	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
Shirmohammadi D, Hong HW.,1989	140.26	30.78	0.93781964	s7, s10, s14, s32, s37
Vanderson, Carneiro, Pereira, Garcia, Ramos.,2005	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
DPSO-HBMO (Niknam T.,2009)	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
DPSO (Niknam T.,2009)	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
PSO-ACO (Niknam T.,2009)	139.53	31.14	0.93781964	s7, s9, s14, s32, s37

DPSO-ACO (Niknam T.,2009)	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
HBMO (Niknam T, Olamaie J, Khorshidi R.,2008)	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
MMSFL(Niknam T, Azad farsani E and Nayeripour M.,2010)	139.53	31.14	0.93781964	s7, s9, s14, s32, s37
The proposed algorithm (without DG)	134.26	33.76	0.94549331	s7, s9, s14, s28, s32
The proposed algorithm(with DG)	131.69	35.02	0.94569627	s7, s9, s14, s28, s32

Table 4: Results obtained by optimizing the voltage deviation of the buses

Method	Minimum deviation of the bus voltage	Minimum voltage (p.u)	Power losses (kW)	Open switches
DPSO-HBMO (Niknam T.,2009)	0.061203	0.9387968	142.80820	s6, s9, s14, s32, s37
DPSO (Niknam T.,2009)	0.061203	0.9387968	142.80820	s6, s9, s14, s32, s37
PSO-ACO (Niknam T.,2009)	0.061203	0.9387968	142.80820	s6, s9, s14, s32, s37
DPSO-ACO (Niknam T.,2009	0.061203	0.9387968	142.80820	s6, s9, s14, s32, s37
HBMO (Niknam T, Olamaie J, Khorshidi R.,2008)	0.061203	0.9387968	142.80820	s6, s9, s14, s32, s37
MMSFL(Niknam T, Azad farsani E and Nayeripour M.,2010)	0.054261	0.9457390	140.06828	s7, s9, s14, s32, s28
The proposed algorithm (without DG)	0.057838	0.9421622	135.95491	s7, s9, s14, s28, s36
The proposed algorithm(with DG)	0.057438	0.9425613	133.38081	s7, s9, s14, s28, s36

As Fig.3 Shows, 5 repeat (iteration) the above algorithm to optimal response is achieved. The high accuracy and speed in the optimization algorithm shows:

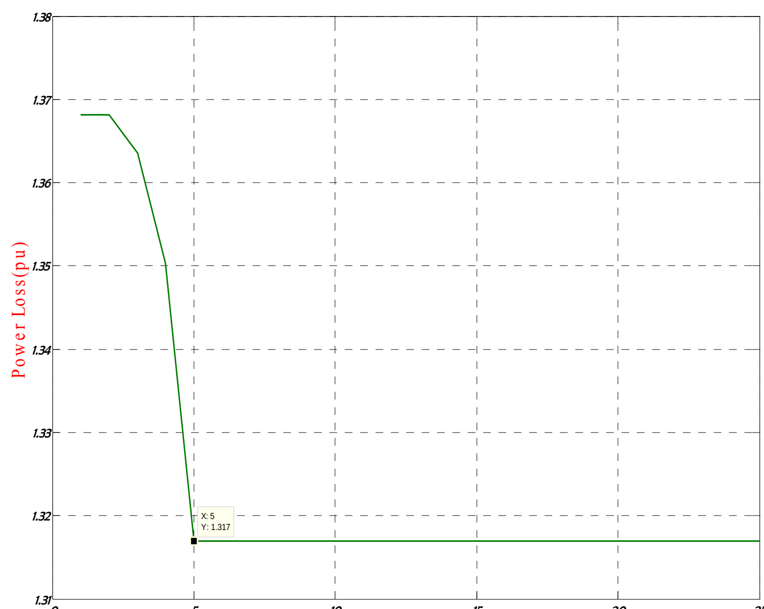

Fig. 3: diagram out put real power loss test system with DGs

Conclusions:

In this paper, an modified honey bee mating optimization (MHBMO) algorithm, make-up distribution network with distributed generations (DGs) for reconfiguration 32 Bus samples (Baran and Wu distribution test system) used, and simulations. The results show that the above algorithm for real power loss minimization to be the most effective and efficient. Because optimization algorithms based on search work, Can be shown that the new arrangement, which can reduce real power loss much better results and optimal response is achieved. The simulation results shown that global or close to global optimum solutions for the system losses, than the other algorithms respectively attained And shown that the presence of DGs real power losses in the network, further decreases.

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