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# A Novel Formulation for Optimal Placement of Diesel/Wind/PV in Distribution System by Honey-Bee Mating Optimization Algorithm

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**Abstract**

In this paper, a novel formulation has been suggested to solve optimal placement of hybrid system based on diesel generator, wind farm and photovoltaic. For this, the proposed objective function has been formulated based on: cost of purchasing equipment, cost of gas split, distance from electrical substation, cost of land acquisition, costs of water split. The calculations are done based on amount of investment for each 3 types of DGs, generating time of each, operation and maintenance costs and bank financial supports (loans). The problem has been optimized by Honey-bee mating optimization (HBMO) algorithm. The honey bee is a social insect that can only survive as a member of a community, or colony. Simulation has been performed on a practical test system in Iran. Results of the proposed algorithm has been compared with related values of Particle Swam Optimization (PSO) algorithm. Results of the HBMO algorithm are compared with related values of genetic algorithm.

Keywords: hybrid system, Diesel generator, Wind farm, Photovoltaic, Honey-bee mating optimization (HBMO) algorithm.
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## 1. Introduction

In optimal design of standalone hybrid renewable energy systems (HRES), reliability of the system in supplying power for a demand load is as important as the levelised cost of energy (LCE) produced by the system. Reliability of a standalone HRES in supplying power depends on various parameters, including, system configuration, size of its components, reliability of each component in terms of operation and the availability of renewable resources [1]. Objective function in [2] has been coded by combination of genetic algorithm to evaluate impacts of DG placement in reliability enhancement and loss reduction as well as voltage profile improvement. In formulation of objective function in [3], technical factor (e.g. minimization of the line loss, reduction in the voltage sag) and economical factor (installation and maintenance cost of the DGs) have been considered. The multi-objective function has been solved using GA and tested on 14, 30 and 34 distribution networks. The proposed objective function in [4] is based on nodal pricing which has been employed to find optimal size and location of DG units for loss reduction, and voltage profile improvement including voltage rise phenomenon. In [5] objective function has been formulated as the weighted sum of reliability indices and power loss, whereas load models, investment costs and DG types have not been considered.

Evolutionary techniques are used in [6-9] to solve this problem. variety of methods have been used in these papers such as combination of algorithms, defining vulnerable buses from voltage stability point of view and finding DG places by dynamic programming search, sensibility test and heuristic curve-fitted technique [10] and straightforward algorithm. The fuzzy algorithm goes beyond “zero and one” values in traditional programming and opens new horizon in programming and computer world. References [11-13] use fuzzy algorithm to find optimum place and capacity for DGs. Authors in [14] applied Mixed Integer Non-Linear Programming (MINLP) algorithm to overcome the problem. In this paper, a novel objective function has been suggested to calculate cost of hybrid system cost. This problem has been solved by HBMO algorithm. This context consists of five sections.

## 2. Problem Formulation

As it has been noted before, the main contribution of this paper is to calculate the net revenue of the investor and the capital investment return time period of installation and operation three type of DGs. The DGs are: gas turbine, wind turbine and photovoltaics. Therefore the problem is formulated to minimize duration of capital investment return time for private sector. The calculations are done based on amount of investment for each 3 types of DGs, generating time of each, operation and maintenance costs and bank financial supports (loans). In following formulations, subscript “g or gas” indicates gas turbine, subscript “w” refers to wind turbine and the “s” subscript is for photovoltaics. The technologies used in allocating each of these three types of DGs are different, thus capital investment for each one of them could be formulated as eq. (1-3). In wind turbine and photovoltaic generation, gas and water piping costs do not add to other expenses, consequently these factors are eliminated from the cost function:

$$Cost_{tg} = CoE_g + CoGS_g + CoC_g + COLA_g + CoWS_g + CoS_g \quad (1)$$

$$Cost_{tw} = CoE_w + CoC_w + COLA_w + CoS_w \quad (2)$$

$$Cost_{ts} = CoE_s + CoC_s + COLA_s + CoS_s \quad (3)$$

In these equations, CoE is the cost of equipment, CoGS stands for Cost of Gas Split, CoC is the Cost of Cabling, CoLA is the Cost of Land Acquisition, CoWS is Cost of Water Split, and CoB is the Cost of the switch. g, w and s indexes are for gas turbine, wind turbine and photovoltaic respectively.

*A) Cost of purchasing equipment:*

The value of this factor is corresponded to the installed MVA and the amount.

*B) Cost of Gas Split:*

If the DG needs the natural gas, cost of gas split and piping from gas station to DG station (depends on distance) should be calculated.

$$CoGS = \alpha_{gas} \cdot PD_{gas} \cdot L_{gas} \quad (4)$$

Which $\alpha_{gas}$ is a given coefficient and its unit is Toman/meter (Toman is Iranian money unit) and $PD_{gas}$is the diameter of pipe and is dependent on MW. $L_{gas}$ is the distance between DG power plant and gas station.

*C) Distance from electrical substation:*

Some cabling should be done from DG station to 63/20 substation, and it can be calculated as follows:

$$DfS = \alpha_{Dfs} \cdot L_{Dfs} \quad (5)$$

In this equation $\alpha_{Dfs}$ is the substation distance coefficient.

*D) Cost of land acquisition:*

This term has been included in the main function based on policy made about industrial zone in Iran. In Iran, the land for DG station located within industrial zone is free and the closer the location could get to the industrial zone; the cheaper will be the land. To consider industrial zone, a part of it will be dedicated to network bar. Thus, the following equation could be concluded:

$$CoLA = a_{CoLA} \cdot \alpha_{Land}(800 + P \times 200) \quad (6)$$

In eq. (6), $a_{CoLA}$ is either zero or one. If the DG station is located in the industrial zone, this coefficient is set to be zero, and if not it would be 1. $\alpha_{Land}$ is price of the land outside the zone. Land prices are varying inside the cities, therefore we consider 60,000 to 100,000 Toman per meter (T/m) for this price. Some of the buses are assumed to be in 60,000 T/m land, some in 70,000 T/m and others are considered to be in 100,000 T/m. DGA is the area occupied the DG power plant.

*E) Costs of water split:*

Some of the DGs need water for cooling procedure, which the corresponding costs should be added to cost function:

$$CoWS = \alpha_{water} \cdot PD_{water} \cdot L_{water} \quad (7)$$

In above equation, $\alpha_{water}$ is e predefined value and it has T/m unit and $PD_{water}$ is the diameter of water pipes and it is proportional to MW. $L_{water}$ is the length of pipe between power plant and gas station. It should be noted that the pipe length is a geometrical component and value of $\alpha_{water}$.

## 3. Honey-Bee Mating Optimization (Hbmo) Algorithm

The honeybee is a social insect that can only survive as a member of a community, or colony. Behaviour of each class provides the needs of the community. The structure of their community involves three different forms: The queen to spawn the drone to intercourse with the queen to produce and the worker bee for the task of keeping the broods and take care of queen and drones and other jobs of the hive. HBMO as many algorithms, which are formed, based on the real behavior of social insects is formed based on the read behavior of honeybee when process of mating. HBMO can be summarized as following steps:

- The algorithm starts by mating flight, where a queen selects drones to form the spermatheca probabilistically.
- New broods are generated with crossover genotypes of the drone and the queen's.
- Workers are used to do the local search on broods (trial solutions).
- A brood of prominent replaces the available queen.

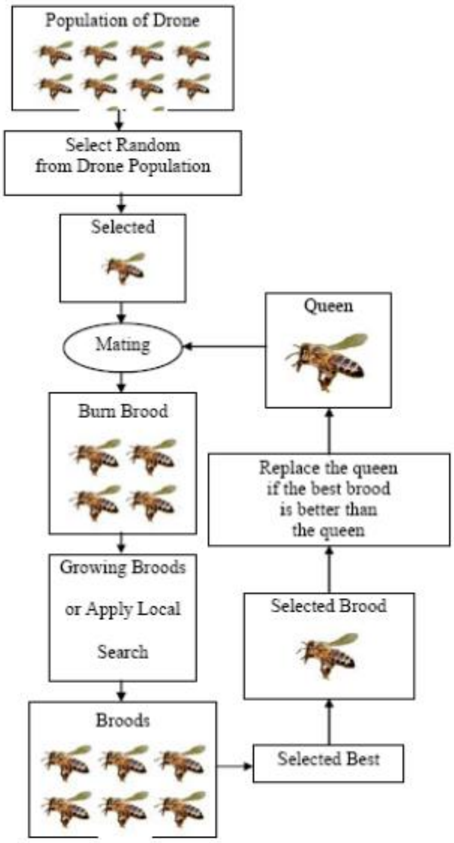


Fig. 1. The HBMO algorithm [15,16].

The start of the process is performed by mating flight by the queen and drones pursuits the queen. In the mating process, the queen copulates multiple times with multiple drones. When mating with drone, its sperm enters the queen spermatheca. The queen fertilizes the eggs using the sperms collected in spermetheca. Among the process, at each step in space, the queen copulates with the drone, which encounters probabilistically with, according to following probability role, which works like a annealing, function

$$prob(D) = e^{-\Delta(f)/s(t)} \tag{8}$$

where, Prob(Q,D) is the probability of adding the sperm of drone (D) to the spermatheca of the queen (Q), Δ(f)is the absolute difference between the fitness of drone (f(D)) and the fitness of the queen (f(Q)) and S(t)is the speed of the queen at time t. Mating flight may resemble the prowl and movement in space and time which the queen encounters with drones in different locations with different speeds. According to the function nature, it is clear that the probability of mating is very high when starting of the flight with higher speed of the queen and or when sufficiency of the drone is close to queen's. After each of relocations in space and passage of time, the queen's speed and energy is dies down according to the following equations:

$$s(t+1) = \beta \times S(t) \tag{9}$$

$$En(t+1) = En(t) - \gamma \tag{10}$$

Where, $\beta$ is a factor dependent to the interval [0, 1] and $\gamma$ is queen's speed and energy drop rate in each transfer. Queen's speed is selected probabilistically at the start of the process. At the start of each flight, a drone is selected by the queen probabilistically according to above probabilistic function. If the mating is successful, the drone's sperm is saved in queen's spermatheca. This continues until the spermatheca fills or queen's speed and energy ends. As the queen saves sperms of different drones in it's spermatheca, it can use various parts of drone's genotype to produce new broods which helps to generate broods (suitable solution).When the queen ends the mating, generation of broods to predefined numbers is started. Each queen selects a sperm from its spermatheca probabilistically and mates. New brood (trial solution) is generated using queen and drone's genotypes. Then the workers come in action to local search to improve burned broods. At the end, if a brood is superior to the queen, the queen is replaced. As HBMO employs the objective function itself and not other auxiliary data, and as the its search is performed in a set of points and not in a single point, and due to using probability roles instead of deterministic roles and because of having suitable mutation operators, all the above factors makes special characteristics of this algorithm with respect to other optimization algorithms to achieve real optimal solution with suitable rate.

## 4. Simulation Results

A radial distribution network in Northwest of Iran has been investigated as test systems. Fig.2 shows single diagram of this system. Results of the HBMO algorithm are compared with related values of genetic algorithm. In GA, Mutation rate, selection factor and the numbers of population and iteration are 0.2, 0.5, 12 and 500, respectively. In HBMO algorithm, Mutation rate and the numbers of population and iteration are 0.2, 12 and 500, respectively. SONY VAIO Corei5, 2.3 GHz, has carried out simulations.

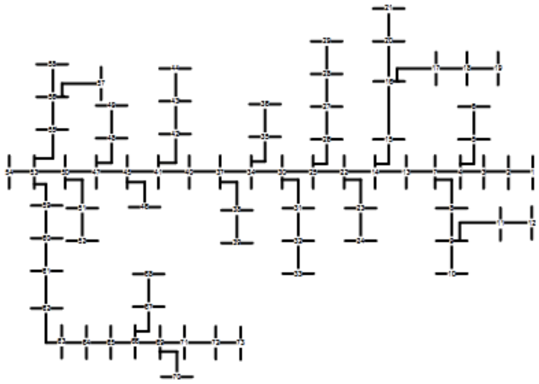

Fig. 2. Single line diagram of practical 73-bus distribution network

In this stage, optimal numbers of the hybrid system that should be installed are determined based on optimal values and capability of the proposed algorithm has been compared with PSO. Table I illustrates optimal values of investment cost for hybrid system.

Table.1.
Optimal values of investment cost

| *Parameter* | *DGen* | *WT* | *PV* |
|---|---|---|---|
| Equipment | 80.00 | 80.00 | 80.00 |
| DfS | 556.16 | 340.44 | 49.56 |
| COGS | 180.60 | 0.00 | 0.00 |
| CoWS | 89.11 | 0.00 | 0.00 |
| COLA | 1177.96 | 179.75 | 1220.50 |
| Cost | 19675 | 15850 | 8320 |

From data of Table I, switches costs for all three types are the same. Cabling and land acquisition cost for photovoltaic is significantly higher, but photovoltaic and wind turbine do not require water and gas piping. As for land acquisition cost, wind turbine comprises the least.

To prove advantages of proposed algorithm, we compared them with corresponding results from genetic algorithm. Simulation was run for 100 times for each test system and the best solution, average of obtained solutions and Best/Iteration (B/It) listed in Table 2. For each test system, simulations have been performed for 100 times and results in three sections have been presented in Table II. These sections are best solution (overall), average of all solutions and best/ iteration (B/It).

Table.2.
Optimal values of investment cost

| *Parameter* | *Technique* | *Value* |
|---|---|---|
| Best | HBMO | 0.499628 |
| | PSO | 0.377812 |
| Mean | HBMO | 0613788 |
| | PSO | 0.418202 |
| B/It | HBMO | 43 |
| | PSO | 41 |
| Running Time | HBMO | 411.005135 |
| | PSO | 254.827210 |

Regarding to Table II, proposed algorithm delivers a better solution. Best possible solution by this method is 0.1218 lower than relative result from PSO. In average of all solutions, this reduction is about 0.1956 and HBMO algorithm reaches the desired optimal result in 21 iterations very much faster than PSO algorithm (almost in half of time PSO reaches the optimal result).

## 5. Conclusion

Main contribution of this paper is proposing a novel objective function to calculate investment and operation cost of hybrid system. For this, a complete hybrid system based on wind turbine and photovoltaic as well as diesel generator has been placed in a practical test system in Iran. The HBMO algorithm has been used to solve the problem. Five parameters have been defined in formulation, which are cost of purchasing equipment, cost of gas split, distance from electrical substation, cost of land acquisition, costs of water split. Capability of the proposed algorithm has been confirmed by comparing its results with PSO algorithm.

## References

[1] A. Maheri, “Multi-objective design optimization of standalone hybrid wind-PV diesel systems under uncertainties, ”Renewable Energy,vol.66, pp.650-661, 2014.

[2] C. L. Borges T., and D. M. Falcao “Optimal distributed generation allocation for reliability, losses, and voltage improvement, ”International Journal of Electrical Power and Energy Systems, vol.28, pp.413-420, 2006.

[3] S. Biswas, and S. Kumar Goswami, “Chatterjee A. Optimum distributed generation placement with voltage sag effect minimization. ”Energy Conversion and Management,vol.53, pp.163-174, 2012.

[4] R. K. Singh, and S. K. Goswami, “Optimum allocation of distributed generations based on nodal pricing for profit, loss reduction, and voltage improvement including voltage rise issue, ”International Journal of Electrical Power and Energy Systems, vol.32, no.6, pp.637-644, 2010.

[5] T. Sami, S. M. Mahaei, and Hashemi Namarvar M.T., Iravani H. “Optimal placement of DGs for reliability and loss evaluation using Dig SILENT software,”10th International Conference on Environment and Electrical Engineering (EEEIC), Italy, 2011.

[6] A. Kumar, and W. Gao, “Optimal distributed generation location using mixed integer non-linear programming in hybrid electricity markets, ”IET Generation, Transmission and Distribution, vol.4, no.2, pp.281-298, 2010.

[7] P. Farhadi, H. Shayeghi, T. Sojoudi, and M. Karimi, “Customer reliability improvement and power loss reduction in radial distribution systems using distributed generations, ”Indian Journal of Science and Technology, vol.5, no.3, pp.2313-2317, 2012.

[8] F. Caballero, E. Sauma, and F. Yanine, Business optimal design of a grid-connected hybrid PV (photovoltaic)-wind energy system without energy storage for an Easter Island's block, Energy, vol. 61, no.1, pp.248-261, 2013.

[9] Zamani M. H., and Riahy G. H., Introducing a new method for optimal sizing of a hybrid (wind/PV/battery) system considering instantaneous wind speed variations, Energy for Sustainable Development, vol.12, no. 2, pp.27-33, 2008.

[10] F. S. Abu-Mouti, and M. E. El-Hawary, “Heuristic curve-fitted technique for distributed generation optimization in radial distribution feeder systems. IET Generation, Transmission and Distribution, vol.5, no.2, pp.172-180, 2011.

[11] M. F. Akorede, H. Hizam, I. Aris, and M. Z. A Ab Kadir, “Effective method for optimal allocation of distributed generation units in meshed electric power systems, ”IET Generation, Transmission and Distribution, vol.5, no.2, pp.276-287, 2011.

[12] A. Barin, L. F. Pozzatti, L. N. Canha, R. Q. Machado, A. R. Abaide, G. Arend, “Multi-objective analysis of impacts of distributed generation placement on the operational characteristics of networks for distribution system planning, ”International Journal of Electrical Power and Energy Systems, vol.32, no.10, pp.1157-1164, 2010.

[13] S. S. Ramalakshmi, “Optimal siting and sizing of distributed generation using fuzzy-EP, ”International Conference on Recent Advancements in Electrical, Electronics and Control Engineering (ICONRAEeCE), pp.470-477, 2011.

[14] Atwa Y. M., El-Saadany E. F., “Probabilistic approach for optimal allocation of wind based distributed generation in distribution systems, ”IET Renewable Power Generation, vol.5, no.1, pp.79-88, 2011.

[15] A. Afshar, O. B. Haddad, M. A. Marino, B. J. Adams, “Honey-bee mating optimization (HBMO) algorithm for optimal reservoir operation,” Journal of the Franklin Institute , vol.344, no.5, pp.452-462,2007.

[16] O. B. Hadad, A. Afshar, M. A. Mario, “Honey-bee mating optimization (HBMO) algorithm: a new heuristic approach for water resources optimization, ”JournalWater Research and Management, vol. 20,no.5,2006, pp.661-680.

[17] G. Eason, B. Noble, and I.N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions, ”Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955.

[18] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.

[19] I. S. Jacobs and C.P. Bean, “Fine particles, thin films and exchange an isotropy, ”in Magnetism, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.

[20] K. Elissa, “Title of paper if known, ”unpublished.

[21] R. Nicole, “Title of paper with only first word capitalized, ”J. Name Stand. Abbrev., in press.

[22] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface, ”IEEE Transl. J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982.

[23] M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.nnual Conf. Magnetics Japan, p. 301, 1982.