# OPTIMAL PLACEMENT OF HYBRID RENEWABLE ENERGY SYSTEM FOR MINIMUM REAL POWER LOSS AND VOLTAGE PROFILE IMPROVEMENT IN RADIAL DISTRIBUTION SYSTEM USING HBMO

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## *ABSTRACT*

*The developments in the technology of distributed generation and the usage of such technology in distribution networks has provided the opportunity to benefit from the usage of these sources to improve the exploitation from the distribution networks some of benefits of distributed generation sources are, loss reduction, voltage profile improvement, increasing network reliability, …. To achieve these goals the problem of allocation, meaning capacity determination, the amount and location of sources are very important. In distribution networks, especially in Iran, because of inefficiency in the loss reduction, voltage amplitude and voltage balance of the voltage profile, the study on the effects of DG sources in order to improve the amplitude and unbalance of the voltage profile and finally give an optimal allocation in reaching are goals is a vital point. In this paper our aim was to optimally allocate hybrid Renewable energy system with Storage System sources. In order to improve the amplitude and voltage unbalance in the system. In other words, our aim was to Delivering the voltage amplitude of buses to acceptable rate, loss reduction and to also reduce voltage unbalance with optimal allocation and DG sources. It is clear that when the sources are allocated in order to increase the voltage amplitude and also a decrease in unbalance, loss will decrease due to an improvement in the voltage profile and a decrease in unbalance. So in this paper optimal placement and sizing of renewable hybrid energy system (Wind/PV/Battery) performed in IEEE 33 bus test system and part of the distribution network in Tehran.*

## INTRODUCTION

Using Distributed Generations can enhance the performance of a power system in many aspects. Employing Distributed Generations in a distribution network has several advantages as [1], reduction in line losses, emission pollutants, overall costs due to improved efficiency & peak saving. Improvement of voltage profile, power quality, system reliability and security and the disadvantages are, reverse power flow, injected harmonics, Increased fault currents depending on the location of DG units. Distributed Generations also has several benefits like energy costs through combined heat and power generation, avoiding electricity transmission costs and less exposure to price volatility [2].

Distributed generation is expected to play an increasing role in emerging electrical power systems. Studies have predicted that DG will be a meaningful percentage of all new generations going on lines. It is predicted that they are about 20% of the new generations being installed. Optimization techniques should be employed for deregulation of the power industry, by applying the best allocation of the distributed generations (DGs). The advancement in technology and the demand of the customers for cheap and reliable electric power has led to an increasing interest in distributed generation. The issues related to reliability and maintenance has impeded the penetration of DG resources in distribution systems [3]. The DG units might bring different benefits such as: network investment deferral, active loss reduction, voltage profile improvement, and reliability improvement. The benefits of DG units highly depend on the size and location of them in the network. Many methods have been proposed in the literature to find the optimal location and size of DG units in the network which have considered various technical aspects such as: voltage limits, feeder capacity limits and number of installed DG units [4]. There are a number of approaches proposed for placement and sizing of DG units and the various authorities has been discussed. In this paper, the problem of optimal renewable hybrid energy system location and sizing in distribution systems is formulated as optimization problem and HBMO is used to solve this problem. The optimal renewable hybrid energy system location and sizing problem is converted to an optimization problem including the network power losses and better voltage regulation. The effectiveness of the proposed HBMO is tested on 33 and 13 bus systems. The results of the simulation clearly show efficiency of proposed method in improving the voltage profile and reduce losses.

## TOTAL REAL POWER LOSS IN A DISTRIBUTION SYSTEM

The total $RI^2$ loss (PL) in a distribution system having *n* number of branches is given by:

$$P_{Lt} = \sum_{i=1}^{n} I_i^2 Ri \tag{1}$$

Here Ii is the magnitude of the branch current and $R_i$ is the resistance of the $I_{th}$ branch respectively. The branch current can be obtained from the load flow solution. The branch current has two components, active component ($I_a$) and reactive component (*Ir*). The loss associated with the active and reactive components of branch currents can be written as:

$$P_{La} = \sum_{i=1}^{n} I_{ai}^2 Ri \quad (2)$$

$$P_{Lr} = \sum_{i=1}^{n} I_{ri}^2 Ri \quad (3)$$

In the first stage optimum location and sizes of the DGs are determined by HBMO algorithm for maximum real loss reduction and in the second stage HBMO algorithm is used to determine sizes of the renewable hybrid energy system.

## IDENTIFICATION OF OPTIMAL DG LOCATIONS

This algorithm determines the optimal size and location of DG units that should be placed in the system where maximum loss saving occurs. Assume that a single-source radial distribution system with *n* branches and a DG is to be placed at bus *m* and α be a set of branches connected between the source and bus m. The DG produces active current $I_{DG}$, and for a radial network it changes only the active component of current of branch set α. The current of other branches (∉=α) are unaffected by the DG. Thus the new active current $I_{ai}^{new}$ of the $i^{th}$ branch is given by

$$I_{ai}^{new} = I_{ai} + D_i I_{DG} \quad (4)$$

The loss $P_{La}^{com}$ associated with the active component of branch currents in the compensated currents in the compensated system (when the DG is connected) can be written

$$P_{La}^{com} = \sum_{i=1}^{n} (I_{ai} + D_i I_{DG})^2 Ri \quad (6)$$

The loss saving S is the difference bet

$$S = P_{La} - P_{La}^{com}$$

(7)

Thus the DG current for the maximum loss saving is

$$I_{DG} = -\frac{\sum_{i=1}^{n} D_i I_{ai} R_i}{\sum_{i=1}^{n} D_i R_i} = -\frac{\sum_{i\in\alpha} I_{ai} R_i}{\sum_{i\in\alpha} R_i} \quad (8)$$

The corresponding DG size is

$$P_{DG} = V_m I_{DG} \quad (9)$$

Vm is the voltage magnitude of the bus *m*. The optimum size of DG for each bus is determined using eqn (9). Then possible loss saving for each DG is determined by using eqn (7). The DG with highest loss saving is identified as candidate location for single DG placement. When the candidate bus is identified and DG is placed, the above technique can also be used to identify the next and subsequent bus to be compensated for loss reduction.

## OPTIMAL SIZING RENEWABLE HYBRID ENERGY SYSTEM

On the design point of view, optimization of the size of a hybrid plant is very important, and leads to a good ratio between cost and performances. Before the system sizing, it's necessary to have enough information about each component of the system. Therefore they are presented in the following sections [5].

### A) Wind Generator

Wind turbine generator needs to consider the cut-in wind speed and the cut-out wind speed. The power of the wind turbine is described in terms of the wind speed by (10):

$$P_{WG} = \begin{cases} 0 & V_W \le V_C, V_W \ge V_F \\ P_R \times \left(\frac{V_W - V_C}{V_R - V_C}\right)^3 & V_C \le V_W \le V_R \\ P_R & V_R \le V_W \le V_F \end{cases} \quad (10)$$

$$V_w = V_w^{measure} \times \left(\frac{h_{hub}}{h_{measure}}\right)^{\alpha} \quad (11)$$

### B) PV cells output model

The output power of each PV array, with respect to the solar radiation power, can be calculated through Eq. (12):

$$P_{pv} = \frac{G}{1000} \times P_{pv,rated} \times \eta_{MPPT} \quad (12)$$

Where, G is perpendicular radiation at array's surface (W/m$^2$), $P_{pv,rated}$ is rated power of each PV array at G= 1000W/m$^2$, and $\eta_{MPPT}$ is the efficiency of PV's DC/DC converter and Maximum Power Point Tracking System (MPPT).

### C) The battery output model

Since the output of PV cells and the turbine is a random behavior the State Of Charge (SOC) of battery bank are constantly changing correspondingly in hybrid systems. When the total output power of the turbine and PV cells is greater than the size of DGs, the battery is in the state of charging, and the charged quantity of the battery at the moment of (t) can be expressed through (13):

$$P_b(t) = P_b(t-1).(1-\sigma) + [P_z(t) - P_l(t)/\eta_{inv}].\eta_{bc} \quad (13)$$

When the total output power of the turbine and PV cells is less than the size of DGs, the battery is in the state of discharging, and the charged quantity of the battery at the moment of t can be expressed through (14):

$$P_b(t) = P_b(t-1).(1-\sigma) + [P_l(t)/\eta_{inv} - P_z(t)]/\eta_{bf} \quad (14)$$

## PROBLEM FORMULATION FOR OPTIMAL SIZING OF RENEWABLE HYBRID ENERGY SYSTEM

### A) Net Present Cost

The Net Present Cost (NPC) of each component is defined as (15):

$$NPC = N\times (\text{Capital cost} + \text{Replacement cost} \times K + \text{Operation maintenance cost} \times \frac{1}{\mathrm{CRF(ir\,,R)}}) \quad (15)$$

Where, N may be number (unit), R is the useful lifetime of the project (here, 20 years). ir is the real interest rate (here, 6%) which is a function of nominal interest rate ($ir_{nominal}$) and annual inflation rate (fr), defined by:

$$ir = \frac{ir_{nominal} - fr}{1+fr} \quad (16)$$

Also, CRF and K are capital recovery factor and single payment present worth, respectively, which are defined as follows:

$$CRF(ir,R) = \frac{ir\times(1+ir)^R}{(1+ir)^R - 1} \quad (17)$$

$$K_i(ir,L_i,y_i) = \sum_{n=1}^{y_i}\frac{1}{(1+ir)^{n\times Li}} \quad (18)$$

Where, L and y are useful lifetime and number of replacements of the component during useful lifetime of the project, respectively. Number of replacements of each component is a simple function of useful lifetimes of the component and the project, it can be calculated by:

$$y_i = \left[\frac{R}{L_i}\right] - 1 \quad \text{if R is dividable to Li} \quad (19)$$

$$y_i = \left[\frac{R}{L_i}\right] \quad \text{if R is not dividable to Li} \quad (20)$$

**1)** Objective function

The objective function is the sum of all net present costs.

$$NPC = NPC_{wg} + NPC_{pv} + NPC_{bat} \quad (21)$$

### B) Constraints

1) Power balance constraint, for any period t, the total power supply from the hybrid generation system must supply the total demand $P_{LOAD}$ with a certain reliability criterion. This relation can be represented by :

$$P_{PV} + P_{WG} + P_{BAT} \geq \text{Size of DG} \quad (22)$$

2) The constraints of the number of turbines, PV cells and batteries;

$$N_{WG}\ ,\ N_{PV}\ ,\ N_{BAT} \geq 0 \quad (23)$$

3) The constraints of the capacity of batteries;

$$\text{Pbmin} \geq \text{Pb} \geq \text{Pbmax} \quad (24)$$

Where, $P_{bmax}$ means the maximum allowable capacity of batteries, which is generally set to rated battery capacity, $P_{bmin}$ means the minimum allowable battery capacity, which is determined by the maximum depth of discharging $DOD$, that calculated by (25):

$$P_{bmin} = (1\text{-DOD}).P_{bmax} \quad (25)$$

## HBMO ALGORITHM

Some researchers have tried in the past to mimic the behavior of honey bees in their algorithms. The Honey Bee Mating Optimization (HBMO) has been proposed by Bozorg Haddad et al [6]. The honey bee is a social insect that can survive only as a member of a community, or colony. A honey-bee colony typically consists of a single egg laying long-lived queen, several thousand drones (depending on the season), workers and is a large family of bees living in one bee-hive and usually contains 10000 to 60000 workers. At the start of the flight, the queen is initialized with some energy content and returns to her nest when her energy is within some threshold from zero or when her spermatheca is full. In developing the algorithm, the functionality of workers is restricted to brood care, and therefore, each worker may be represented as a heuristic which acts to improve and/or take care of a set of broods. A drone mates with a queen probabilistically using an annealing function as:

$$prob(Q,D) = e^{\frac{-\Delta(f)}{S(t)}} \quad (26)$$

Where *Prob (Q, D)* is the probability of adding the sperm of drone *D* to the spermatheca of queen *Q* (that is, the probability of a successful mating); $\Delta(f)$ is the absolute difference between the fitness of *D* (*i.e., f (D)*) and the fitness of *Q* (*i.e., f (Q)*); 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 both 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:

$$S(t+1) = \alpha_{HBMO} \times S(t) \quad (27)$$

$$E(t+1) = E(t) - \gamma_{HBMO} \quad (28)$$

Where $\alpha_{HBMO}(t)$ is speed reduction factor and $\gamma_{HBMO}$ is the amount of energy reduction after each transition ($\alpha, \gamma \in [0,1]$).

Thus, HBMO algorithm may be constructed with the following five main stages:

Step 1: The algorithm starts with the mating flight

Step 2: Creation of new broods by crossoverring the drones' genotypes with the queen's (Breeding process).

Step 3: Use of workers (heuristics) to conduct local search on broods (trial solutions).

Step 4: Adaptation of workers' fitness based on the amount of improvement achieved on broods

Step 5: Replacement of weaker queens by fitter broods.

In general, the whole process of standard HBMO algorithm is presented in Figure 1.

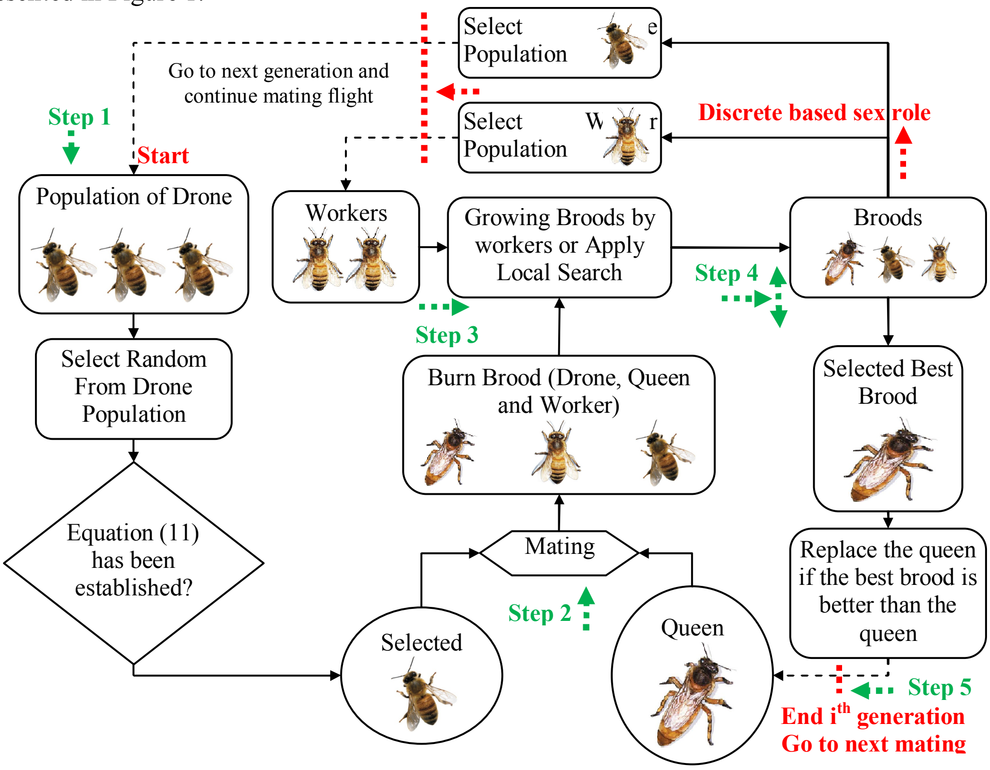


Figure1. The HBMO technique

## TEST SYTEM

This methodology is tested on IEEE 33 bus system consists of 33 nodes and 32 branches. The base voltage for this system is 12.66 kV and base MVA is 10 and part of distributions network of Tehran (Khoda bande loo) consists of 13 nodes and 12 branches, substation 63/20 kv. The base voltage for this system is 20 kv

## RESULTS AND DISCUSSION

In this paper optimal placement and sizing of renewable hybrid energy system (Wind/PV/Battery) performed in IEEE 33 bus test system and part of the distribution network in Tehran. Initially location and size of DGs is determined. Then, according to weather central parts of Iran the size and cost of the hybrid system is determined. The results of the simulations in MATLAB for this test systems presented in figures and tables below. The results of the simulation clearly show efficiency of proposed method in improving the voltage profile and reduce losses.

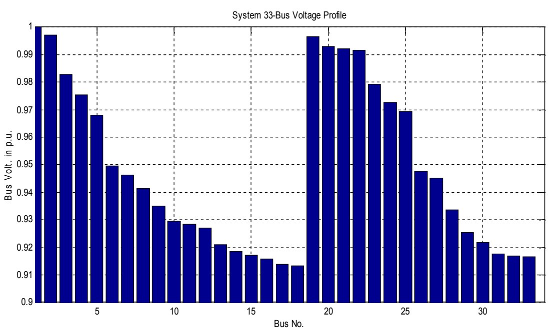


Figure2. Bus voltage profiles before placement of renewable energy sources (33bus-test system)

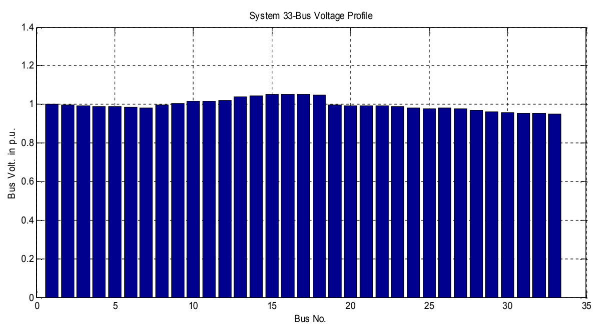


Figure3. Bus voltage profile after the placement of renewable energy sources (33bus-test system)

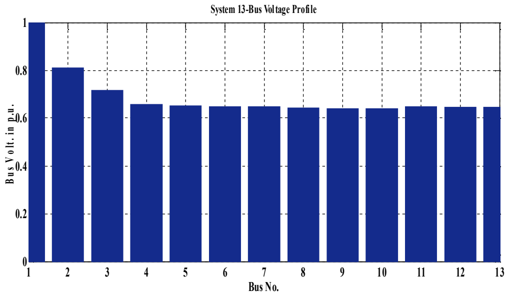


Figure4. Bus voltage profiles before placement of renewable energy sources (33bus-test system)

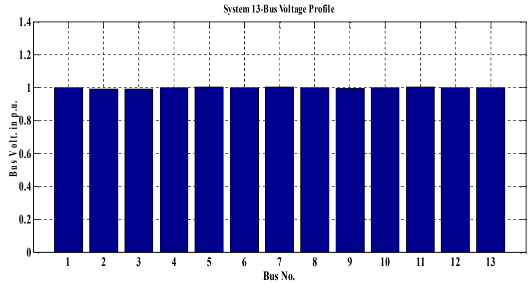


Figure5. Bus voltage profile after the placement of renewable energy sources (33bus-test system)

Table1. Location and size of DG (33bus-test system)

| Loss (MW) | Location DG | Size of DG (MW) | ittration |
|---|---|---|---|
| 0.1111 | 6 | 2.5911 | 1 |
| 0.1111 | 6 | 2.5901 | 2 |
| 0.1111 | 6 | 2.5897 | 3 |
| 0.1111 | 6 | 2.5911 | 4 |
| 0.1111 | 6 | 2.5911 | 5 |

Table2. Results HBMO algorithm for hybrid systems (in 33bus-test system)

| Cost for 20 year | No of WT | No of PV | No of Battery | ittration |
|---|---|---|---|---|
| 35959 | 8 | 0 | 3 | 1 |
| 42752 | 0 | 26 | 2 | 2 |
| 35456 | 4 | 9 | 3 | 3 |
| 35385 | 5 | 8 | 2 | 4 |

Table3. Location and size of DG (13 bus-test system)

| Loss (MW) | Location DG | Size of DG (MW) | ittration |
|---|---|---|---|
| 0.0417 | 5 | 2.0220 | 1 |
| 0.0417 | 5 | 2.0218 | 2 |
| 0.0417 | 5 | 2.0219 | 3 |
| 0.0417 | 5 | 2.0220 | 4 |
| 0.0417 | 5 | 2.0220 | 5 |

Table4. Results HBMO algorithm for hybrid systems (in 13 bus-test system)

| Cost for 20 year | No of WT | No of PV | No of Battery | ittration |
|---|---|---|---|---|
| 32547 | 6 | 0 | 2 | 1 |
| 34672 | 0 | 19 | 2 | 2 |
| 31456 | 3 | 7 | 3 | 3 |
| 29678 | 2 | 9 | 3 | 4 |

## CONCLUSIONS

In this paper, the HBMO algorithm is presented for optimal placement and sizing of renewable hybrid energy system. The proposed HBMO algorithm for optimal placement and sizing of hybrid energy system is easy in performance without additional computational complexity. The capability of the proposed approach is tested on 33 and 13 (Khoda bande loo) bus systems to minimize the losses, increase the voltage stability and improve the voltage profile. The simulation results show that the HBMO yields has better convergence characteristics.

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