Optimal Allocation and Size of Multi-type Distributed Generators in Distribution System Using Dragonfly Optimization Algorithm

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Abstract

In this paper, a very newly swarm optimization technique namely a dragonfly optimization algorithm (DFOA) is used to allocate and size the distributed generators (DGs) along distribution networks. The multi-objective function is adapted to reduce the total system power loss, decrease the cost of DGs and improve the voltage profile with the resolve of improving the operating performance. In addition, the loaded power factor and reduction in network reactive power loss are spotted. The proposed methodology is agreed to challenge of loss sensitivity to decide the final sitting and size of the DGs. Two types of the DGs are studied and investigated. The proposed method is established and validated finished in distribution networks with different sizes and complexities. The DFOA methodology can efficiently produce high-quality solutions compared to other competitive techniques such as Harmony Search (HS).

Index Terms— *Multi-Objective Function (MOF), Dragon Fly Algorithm (DFA), Harmony Search Algorithm (HSA), Power Factor (PF), Voltage Deviation (ΔV)*

I. INTRODUCTION

Electrical distribution systemsneed an effective operating development for economic feasibility and power quality determinations. Thus, Distributed Generators (DGs) is the idea of regionalizing the power generation by connecting small generating units to the distribution system. These generation units can be both renewable (PV solar, wind, geothermal, mini-hydro, biomass) [1] and nonrenewable (fuel cell, gas turbines) energy. Nowadays, central power plants are the chief source of power supply, though DGs technology is ahead extensive supper interest in the electric power system because of their paybacks like economical, technical and especially environmental.

Literally, numerousmethods have been established to find out the best location and size of the DGs. Analytical approaches have been stated for single- and multiple-DG allocations [2,3], optimal power flow [4], mixed-integer nonlinear programming [5], and mixed-integer linear programming [6].Currently years, many intellectual and meta-heuristic optimization techniques have been applied in a varied range of topics in engineering, including the DG allocation problem.These several methods are genetic algorithm (GA) [7, 8], goal programming [19], the ant colony system algorithm [9], the harmony search algorithm [10], cat swarm optimization [11], particle swarm optimization (PSO) [12,13], artificial bee colony (ABC) [14], the imperialist competitive algorithm (ICA) [15], gray wolf technique [16] and differential evolution (DE) [17] have been applied to place single or multiple DGs for various objectives.

Three categories of DGs are considered and investigated for their effects in reducing the total system power loss,increase annual cost saving and voltage profile improvements.A load power factor (PF) and reactive power loss are observed. The proposed procedure is applied to two benchmark system (IEEE14-bus and IEEE30-bus) [18,19] systems for examination its effectiveness and accuracy. Several cases with single and multiple DGs of different types are demonstrated. Essential comparisons are in place with other competing approaches.

II. The Dragon Fly Optimization Algorithm (DFOA)

In nature, a lot of small insects will be hunted by the dragonflies which are considered as small hunters. The baby of dragonflies called (Nymph) come before other insects or small fishes. The interesting fact about the behavior of dragonflies has unique swarming. There are two purposes for dragonflies swarm hunting and migration. The former is called static (feeding) swarm, and the latter is called dynamic (migratory) swarm. [20]

For the first purpose (static swarm), a small groups of dragonflies will be make and fly back and forth over a small area to hunt other flying victims such as butterflies and mosquitoes as shown in Fig (1) , the chief characteristics of a static swarm that the rapid changes and local movements in the flying path.

For the second purpose (dynamic swarms), although, in the migrating a huge number of dragonflies make the swarm in one direction over long distances , the interesting thing of the DFO algorithm creates from static and dynamic swarming behaviors these two swarming behaviors are very comparable to the two main phases of optimization using meta-heuristics: exploration and exploitation. In the static swarm, the main objective of the exploration phase is flying of Dragonflies over different areas in a static swarm though; in the exploitation phase the dragonflies is encouraging fly in bigger swarms and along one direction.

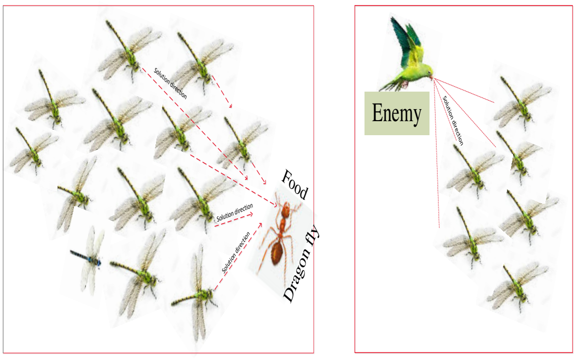

Fig .1Idea of DFO Algorithm

The behavior of swarms can divided in three basic principles,a)Separation, which refers to the static collision avoidance of the individuals from other individuals in the neighborhood,b)Alignment, which indicates velocity matching of individuals to that of other individuals in neighborhood, c) Cohesion, which refers to the tendency of individuals towards the center of the mass of the neighborhood

The objective of any swarm is existence a life, so all of the individuals should be attracted towards food sources and distracted outward enemies. Considering these two behaviors, there are five main factors in position updating of individuals in swarms, can modeled all of these behaviors in mathematically form as below:

The separation is calculated as,

$$S_i = -\sum_{j=1}^{N} X - X_j \qquad (1)$$

Where,X is the position of the current individual

$X_j$isthe position j-th neighboring individual

Nisthe number of neighboring individuals

Alignment is calculated as follows:

$$A_i = \frac{\sum_{j=1}^{N} V_J}{N} \qquad (2)$$

Where,$X_j$is the velocity of j-thneighboring individual.

$$C_i = \frac{\sum_{j=1}^{N} X_i}{N} - X \qquad (3)$$

Where X is the position of the current individual, N is the number of neighborhoods, and $X_i$shows the position j-thneighboring individual.

Attraction towards a food source is calculated as follows:

$$F_i = X^{+} - X \qquad (4)$$

Where,X is the position of the current individual

$X^{+}$is the position of the food source.

Distraction outwards an enemy is calculated as follows:

$$E_i = X^{-} - X \qquad (5)$$

Where, X is the position of the current individual

$X^{-}$is the position of the enemy.

The dragonflies behavior is expected to be the grouping of) these five corrective patterns simulate their movements and update the position of artificial dragonflies in a search space.Two directions are considered: step (ΔX) and position (X). The step vector is equivalent to the velocity vector as particle swarm optimization where the framework of the PSO algorithm is developed based on the DFOalgorithm, the step vector as the direction of the movement of the dragonflies and defined as follows[20]

$$\Delta X_{i+1} = (sS_i + aA_i + cC_i + f F_i + eE_i) + w\Delta X_i \quad (6)$$

Where,(S_i)is the separation weight while indicates the separation of the i-th individual,

(a) is the alignment weight

(A_i) is the alignment of i-th individual, (c) indicates the cohesion weight

(C_i)is the cohesion of the i-th individual,

(f) is the food factor

(F_i) is the food source of the i-th individual,

(e) is the enemy factor,

(E_i)is the position of enemy of the i-th individual,

(w) is the inertia weight, and t is the iteration counter.

After calculating the step vector, the location vectors are calculated as follows [20];

$$X_{t+1} = X_t + \Delta X_{t+1} \qquad (7)$$

Where, t is the current iteration.

With all five factors separation, alignment, cohesion, food, and enemy factors (s, a, c, f, and e), during optimization, there are different explorative and exploitative behaviors can achieved. Neighbors of dragonflies are very important, so a neighborhood can draw as circle in a 2 D or sphere in a 3D space with a certain radius is assumed around each artificial dragonfly, for example of swarming behavior of dragonflies with increasing neighborhood radius using the proposed mathematical model, As illustrated in the previous section, dragonflies only show two types of swarms: static and dynamic

While maintaining proper separation and cohesion in a dynamic swarm of dragonflies tend to align their flying in a static swarm, though, alignments are very low while cohesion is high to attack victims. So, allocate dragonflies with high alignment and low cohesion weights when exploring the search space and low alignment and high cohesion when exploiting the search space. For transition between exploration and exploitation, the ranges of neighborhoods are increased proportional to the number of iterations. Another way to balance exploration and exploitation is to adaptively tune the swarming factors (s, a, c, f, e, and w) during optimization.

Hence, how the convergence of dragonflies is certain during optimization. It is essential for the dragonflies to change their weights adaptively for transiting from exploration to exploitation in the search space , also assumed that more dragonflies will be with dragonflies to adjust flying path as optimization process evolutions. In other word, the swarm behavior become one group at the final stage of optimization to converge to the global optimum will be increased by the neighborhood area , The food source and enemy are chosen from the best and worst solutions that the whole swarm is found so far. This causes convergence near promising areas of the search space and divergence outward non-promising regions of the search space.In Fig. (2) The flow chart of DFOA

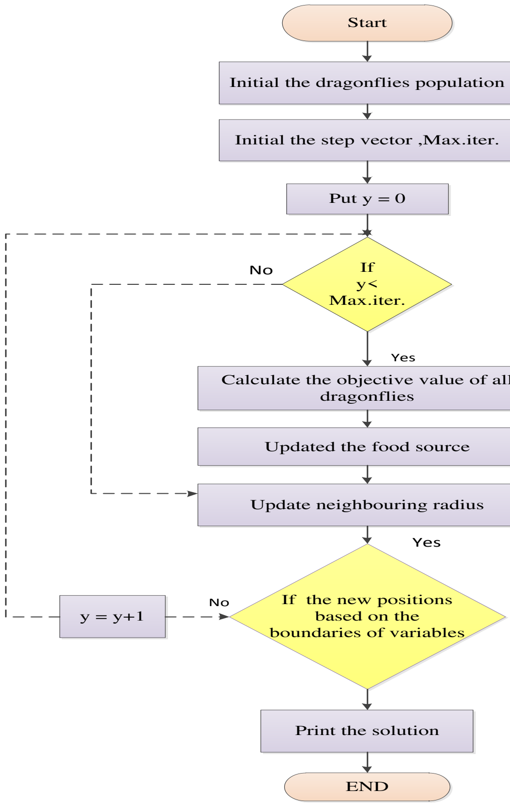

Fig. 2 Flow Chart of Dragon Fly Algorithm

III. MATHEMATICAL FORMULATION AND DESCRIPTION

A multi-objective optimization process, expressed as a constrained non-linear optimization problem, is planned for DGsplacement indistribution system. The problem is conventional as an optimal power flow model that has a multi-objective optimization function. Four objectives have been considered and optimized either successively while sustaining system constraints and while the voltage within suitable limits.

a) The total active loss minimization (P_l),
b) The total reactive loss minimization (Q_l),
c) Reduction of Voltage deviation (ΔV)
d) Maximization annual cost saving (AC)

$$\text{Min}\, f(P_l, Q_l, \Delta V, AC) = [\, f_1(P_l), f_2(Q_l), f_3(\Delta V), f_4(AC)\,] \quad (8)$$

f_1 The system active power loss
f_2: The system reactive power loss
f_3: load voltage deviation
f_4: Annual investment cost

First, the objective function f_1 is to minimize the system active power loss

$$\text{Min } f_1(P_l) = P_l = V \times I \cos\emptyset \approx I^2R \quad (9)$$

Second, objective f_2 is to minimize the system reactive power loss

$$\text{Min } f_2(Q_l) = Q_l = V \times I \sin\emptyset \quad (10)$$

The third, objective f_3 is to minimize the bus voltage deviation VD:

$$\text{Min } f_3(\Delta V) = \sum_{K=1}^{nB} \left(\frac{V_j^{ref} - V_j}{V_j^{ref}} \right) \quad (11)$$

The voltage constraints:

$$V_{min} \leq V_j \leq V_{max} \quad (12)$$

$$S_{min} \leq S_j \leq S_{max} \quad (13)$$

S : the transmission capacity of branch j
V : the voltage of branch j

The forth objective is to minimize the annual investment cost.

In this paper, three cost components are considered: (a) the capital cost of DGs installation C_1 (\$/kW); (b) the annual variable operating and maintenance cost C_2 (\$/kwh) of DGs;(c) the fixed operation and maintenance costs of GDs C_3 (\$/kW-year)[20].

$$\text{Min (AC)} = \sum_{j=1}^{NDG}\left(\left(\frac{r*(1+r)^m}{(1+r)^{m-1}}\right) \times (C_{Cap.} + (h * C_{variable} + C_{fixed}) * n)P_{DG}\right) (12)$$

$C_{Cap.}$ Annual equipment installation cost (\$/kW)C_1
r: Annual interest rate.
m: number of years during which equipment installation cost take 5 years
NDG number of dg installed in the buses
$C_{variabl}$ the annual variable operating and maintenance cost (\$/KWh)C_2
h the number of operating hours in year , take 8 hours in day (8*8760) in year
C_{fixed} the fixed operating and maintenance cost (\$/KW-year)C_3

IV. GENERAL ASSUMPTIONS

Study Period is 5 Years. Loads are constant PQ loads with constant power factor and constant during study period. DG power factor is unity. All DG resources can install at every bus within system (except at the slack bus and generator buss). Interest rate is 10 %.The parameters, namelyC_1,C_2 andC_3 in Equ. (14) givethe values given in Table 1,[1].

Table -1 Constantof DGs [1]

	Biomass	Micro Turbine	Wind
C1 (\$/KW)	3830	15	95
C2 (\$/KWh)	2250	3.67	6.31
C3 (\$/KWh)	1980	0	60

V. RESULTS AND DISCUSSION

Case1, using trial and error, concept for two distribution systems (IEEE14-bus and IEEE30-bus), several test cases are implemented with random size and location, the numbers of DGs are scheduled to attain DGs allocation problem.Tables(2) and (3), after installing the DGs in the weakest buses using trial and error concept

Table.2 Simulated Results for IEEE14-Bus for Random DGs Installation

	Without DG	One DG	Two DGs	Three DGs
Active power loss Mw	21.786	20.140	20.387	18.686
Reactive power loss Mvar	67.7726	59.3905	59.275	50.7729
Allocation	--	14	13&9	14&12&9
Size (Mw)	--	9	6&8	8&6&4
PF	0.90	0.91	0.91	0.93

Table.3 Simulated Results for IEEE30-Bus for Random DGs Installation

	Without DG	One DG	Two DGs	Three DGs
Active power loss Mw	41.96	39.12	37.38	37.10
Reactive power loss Mvar	131.94	119.23	110.49	109.42
Allocation		30	28&25	29&25 &21
Size (Mw)		10	9&7	10&8& 4
PF	0.82	0.83	0.84	0.82

After trial and error, the results are obtained, due to random installation of DGs, although these results are not the best solutions for optimum size and allocation of DGs but it will improve the performance of the systems. Thus suggested optimization techniques will implemented on the two test systems to attain the best size and location to minimize the fitness function.

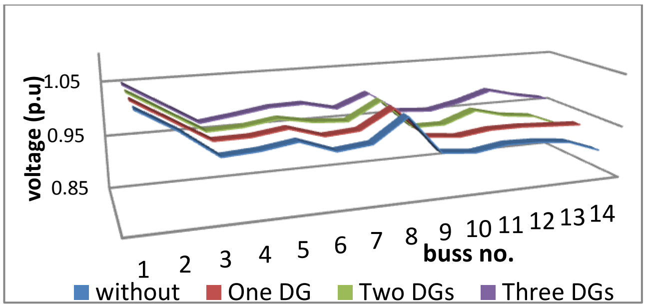

Fig.3 Voltage Profile of IEEE14-Bus System for Case1-a

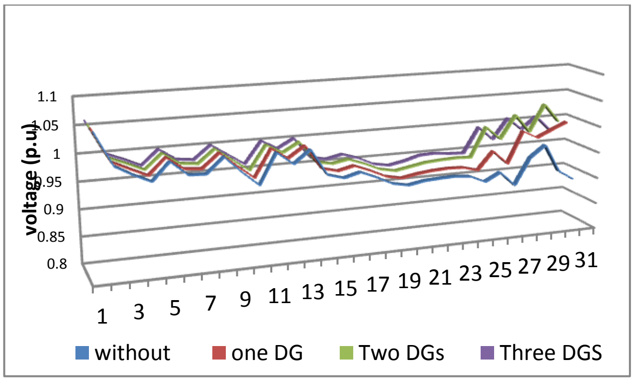

Fig.4 Voltage Profile ofIEEE30-Bus System for Case1-b

Figs.3 and 4 shows the voltage profile of IEEE14-bus system and IEEE30-bus system , its obtained that the voltage profile for three DGS installed is the best.

Case 2-a the simulated resultsof IEEE14-bus system areobtained with the suggested techniques MFO and HSAon three types of DGs technologies. Table (4) shows DFA has the best performance compared to HSA, the reduction of total system loss using HS is less than by 5.5% , when applying DFA improve the power factor to 0.996 .

Table (4) Simulated Results for Proposed Techniques

Parameters	Without DG	With DG	
		HSA	DFA
Active loss (MW)	21.7861	11.706	10.754
Reactive loss (MVAR)	67.7726	19.330	15.547
Total Loss reduction (%)	0	68.255	73.445
Power factor	0.905	0.993	0.996
Objective function	14.147	4.88	4.15

Table (5) illustrates the cost of DGs installed and the annual cost saving in M$ for three types of DGs.It is obvious that the wind source has the most economic type installed with increasing the annual saving 2.3M$ than other technology.Also the DFA is more economical than HSA where it chooses best size and location for DGs to get the best performance with less cost. From table 5 also, it is clear that save 0.339 M$ due to the best size and location of DGs.

Table (5) Annual Cost Saving for Three Typed of DGs Installed

	Biomass		Micro Turbine		Wind	
	HS	DF	HS	DF	HS	DF
Cost of DG installed(M$)	1.98	1.79	0.39	1.79	0.39	0.007
Annual cost saving(M$)	23.1	24.8	24.11	24.7	24.1	26.5

Fig(5) illustrates the voltage profile of IEEE14-bus system with the proposed techniques; the DFA has the best performance for improving the voltage profile.

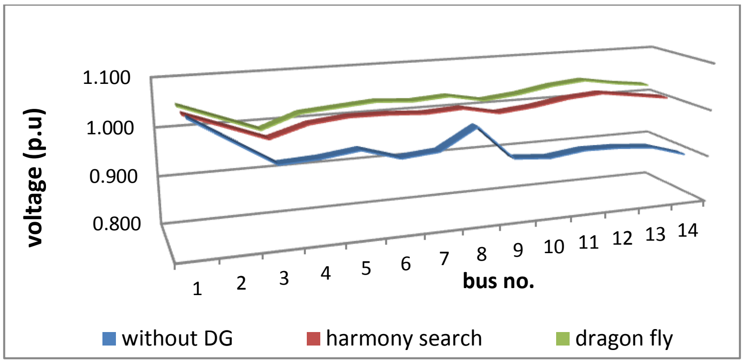

Fig .5 Voltage Profile of IEEE14-Bus System case 2-a

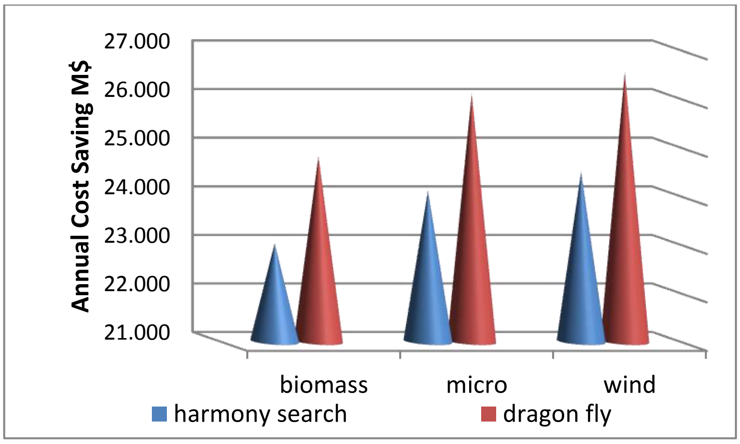

Fig .6Annual Cost Saving of IEEE14-Bus System 2-a

The objective functions have been optimized and their values are shown in Fig.(7). DFAis more effective and accuratedue to DGsexisting in the systems as shown in Fig. (8).

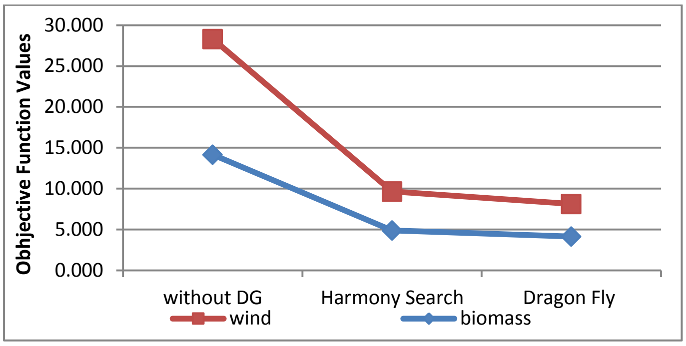

Fig.7 Objective Function for IEEE14-bus system case 2-a

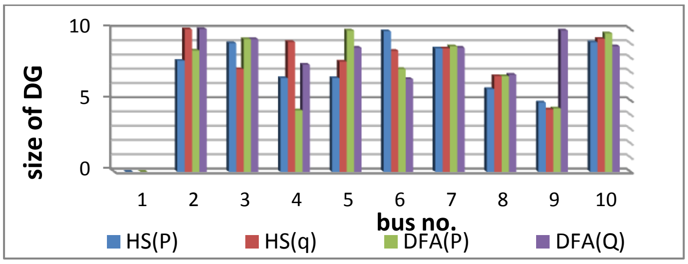

Fig .8 DGs installed in IEEE14-bus system case 2-a

Case 2-bMFO and HSA techniques are implemented on IEEE30-bus system for three types of DGs technologies. It is obvious from Table (6), shows the DFA has the best performance as it decreases the total power system loss to 4.3% compared to HSA; improve the power factor to 0.968 and minimizes the objective function.

Table (7) showsthe cost of DGs installed and the annual cost saving in M$ for the three types of DGs, It is found that the wind source is the most economical type installed with increasing the annual saving to 3.3M$ than other technology.Also the DFA is more economical than HSA as it choosesthe best size and location of DGs to give the best performance with less cost. DFA save 0.4 M$ because of its effective performance

Table (6) Simulated Results for Proposed Techniques

Parameters	Without DG	With DG	
		HSA	DFA
Active loss (MW)	29.6515	15.9525	14.9734
Reactive loss (MVAR)	83.8846	25.1496	21.4410
Total Loss reduction (%)	0	66.5259	70.6063
Power factor	0.8436	0.9536	0.9685
Objective function value	17.8491	6.4179	5.6875

Table (7) Annual Cost Saving for the Three Types of DGs Installed case 2-b

	biomass		Micro turbine		Wind	
	HS	DF	HS	DF	HS	DF
Cost of DG installed(M$)	1.75	1.705	0.44	0.47	.012	0.007
Annual cost saving (M$)	28.7	30.50	30.6	33.2	30.6	36.4

Fig.(7) illustrates the voltage profile of IEEE30-bus system with the proposed techniques.The DFA has the best performance for improving the voltage profile.

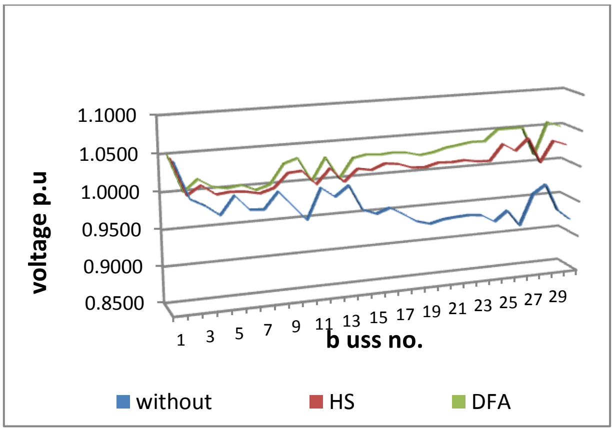

Fig .8 VoltageProfile of IEEE 30-Bus System case 2-b

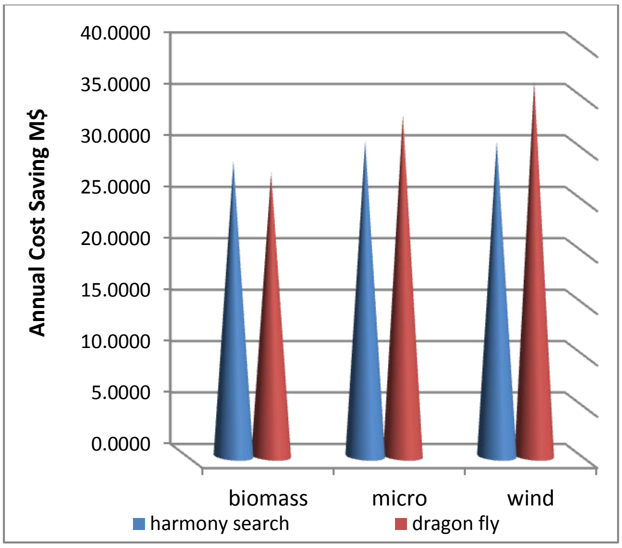

Fig .9 the annual cost saving of IEEE30-bus system case 2b

Fig.8 shows the voltage profile of IEEE30-bus system, it's obvious that the DFA has the best voltage profile, while Fig.9 shows that DFA has the large annual cost saving for IEEE30-bus system with wind energy.

The objective functions have been optimized and their values are shown in Fig (10), DFA has more effective and accuracy due to the value and sitting of DGs in the systems as shown in Fig.(11)

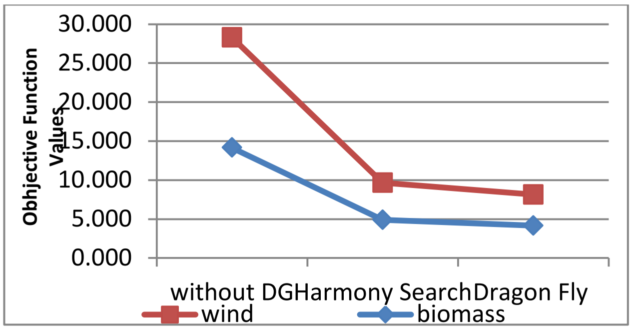

Fig .10 Objective Function values for IEEE 30-bus system-case2b

Fig.10 illustrated that DFA has the minimum objective function, Fig.11 shows the sizing and location of DGs , it's obvious that the DFA has the optimal size and placement for DGs to get all the benefits .

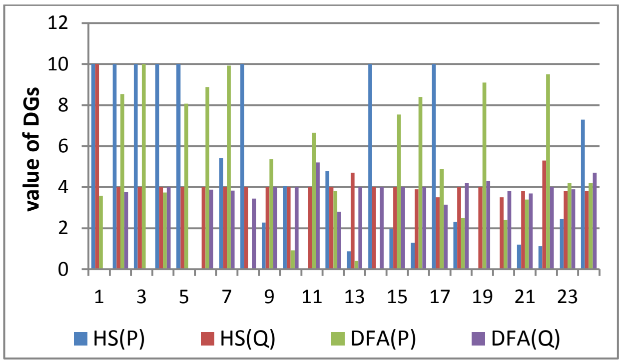

Fig .11 DGs Installed in IEEE30-Bus System-case2b

VI. CONCLUSIONS

The impact of appropriate allocation and size of DG is very important. This paper presents a new approach for optimum location and size of distributed generation in distribution systems. DFA is more effective and accurate for optimal sizing and locationhas bee of the DGs .The proposed techniques implemented on two benchmark systems IEEE14-Bus and IEEE30-Bus system, the comparison between DFA and HSAlead to the DFA has the best results. a) IEEE14-Bus system the minimum voltage value is 1.029 p.u , reduction in total system loss up to 73.4% and annual cost saving is 26.2 (M$) of the distribution system, b) IEEE30-Bus system the technique was more effective, the minimum voltage value is 1.3 p.u , reduction in total system loss up to 93.1% and annual cost saving is 36.4 (M$) of the distribution system

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