OPTIMAL PLACEMENT OF DISTRIBUTED GENERATION IN RADIAL DISTRIBUTION SYSTEM USING DRAGONFLY ALGORITHM

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Abstract: This paper presents a method for optimal placement of Distributed Generation (DG) in radial distribution system using Dragonfly Algorithm (DA). Minimization of active power losses of distribution system has been considered as an objective function. Voltage limits and thermal limit of feeders in radial distribution system have been considered as constraints of optimization problem. The proposed method has been implemented on PG & E 69 bus and IEEE 15 bus radial distribution system. Reduction of active power losses of radial distribution system by choosing proper location and size of DG units using proposed method has been observed in simulation results.

Index Terms - Distributed Generation (DG), Dragonfly Algorithm (DA), Active power losses, Radial distribution system (RDS), Optimal placement.

1. INTRODUCTION

In the last decade, the penetration of embedded generator resources in distribution network has been increased globally. New local government policies towards reduction in greenhouse gas emissions and mitigation of global warming is the main reason for such penetration. Loss reduction, on peak operating cost reduction, improvement in network reinforcement horizon, service quality, reliability, power quality and voltage support [1], [2] are the benefits seen by the penetration of EG units into the distribution system. Traditional distribution systems are passive in nature. These passive distribution systems are transformed into active distribution system like transmission system upon integration of DG units [3]. There are many technical issues like increasing steady state voltage at minimum voltage bus and reduction of active power losses have been considered for connecting the DG units in to the radial distribution system [4].

Many approaches have been existing in literature for determining the optimal location and size of DG units in radial distribution system. Conventional optimization techniques, metaheuristic techniques and artificial intelligence are normally used to solve this type of optimal placement problem [5]. Conventional techniques usually suffer from the problem of convergence at local minimum instead of at global. Hence these methods are not suggestible for solving problems which have a large number of local minimum points. Whereas heuristic and evolutionary algorithms are powerful and effective for solving complex real time problems [6].

Ant Colony Search Algorithm (ACSA) was used for solving the optimal allocation problem in [7]. This algorithm is inspired from the natural behaviour of the ant colonies on how they find the food source and bring them back to their nest by building the unique trail formation. However, the rates of ant colony regulating parameters need to be determined using experimental approach [8].

Evolutionary Programming (EP) was used to solve the optimal placement of DG units in radial distribution system in [9]. In this method sensitive indices which are developed from voltage stability index have been used for selecting the optimal location of DG units. Particle Swarm Optimization algorithm was used for identifying the optimal location and size of DG units in radial distribution system based on active power losses in [10]. Genetic Algorithm was used for optimal placement of DG based on active power losses and voltage rise in [11] and based on active power losses in [5]. However genetic algorithm has some flaws like problem in finding the exact solution and slow convergence [12].

In this paper first time Dragonfly Algorithm (DA) has been used for solving the optimization problem i.e. optimal allocation of DG units in radial distribution system. Minimization of active power losses of distribution system has been considered as an objective function. Location in terms of bus number in distribution system and size of DG in terms of generating capacity are considered as decision variables. Voltage limits at each bus and thermal limit of each line in distribution system have been considered as constraints in this optimization problem.

The remaining part of the paper has been organized as:

Section II describes about problem formulation, section III presents simulation results of the proposed method and section IV presents conclusions of this paper.

2 .PROBLEM FORMULATION

The optimization problem for optimal allocation of DG units in radial distribution system has been designed in such a way that active power losses of distribution system were minimized. Objective function for this optimization problem has been considered as shown in equation 1 and constraints are designed as shown in equation 2.

$$\text{Minimize Ploss} \qquad (1)$$

$$\left.\begin{array}{l} V_i^{\min} \le V_i \le V_i^{\max} \\ I_l \le I_l^{\max} \\ P_g^{\min} \le P_g \le P_g^{\max} \\ 2 \le loc \le n \end{array}\right\} \qquad (2)$$

In this paper the above stated optimization problem has been solved using Dragonfly Algorithm [13].

2.1 Dragonfly Algorithm (DA):

DA was developed based on swarming behavior of swarming behavior of dragonflies. There is two type of swarming exist like static and dynamic. In static swarm, dragonflies make small groups and fly back and forth over a small area to hunt other flying preys. In dynamic swarms, massive number of dragonflies make the swarm for migrating in one direction over long distances. Dynamic swarming with high alignment and low cohesion is related as exploration phase and static swarming with low alignment and high cohesion can be related to exploitation in optimization problem. The five main factors considered in swarming of dragonflies are separation, alignment, cohesion, attracting towards food and detracting away from enemy, and these are mathematically modeled as shown in equations (3), (4), (5), (6) and (7) respectively.

$$S_i = -\sum_{j=1}^{N} X - X_j \qquad (3)$$

$$A_i = \frac{\sum_{j=1}^{n} X_j}{N} \qquad (4)$$

$$C_i = \frac{\sum_{j=1}^{n} X_j}{n} - X \qquad (5)$$

$$F_i = X^+ - X \qquad (6)$$

$$E_i = X^- + X \qquad (7)$$

As per dragonfly algorithm step of dragonflies updated using equations (8). If neighbourhood exist then position of dragonflies updated using equation (9) otherwise use equation (10).

$$\Delta X_{t+1} = (sS_i + aA_i + cC_i + fF_i + eE_i) + \omega \Delta X_t \quad (8)$$

$$X_{t+1} = X_t + \Delta X_{t+1} \qquad (9)$$

$$X_{t+1} = X_t + Levy * X_t \qquad (10)$$

Complete flowchart for solving any optimization problem Using dragonfly algorithm is shown in Fig. 1.

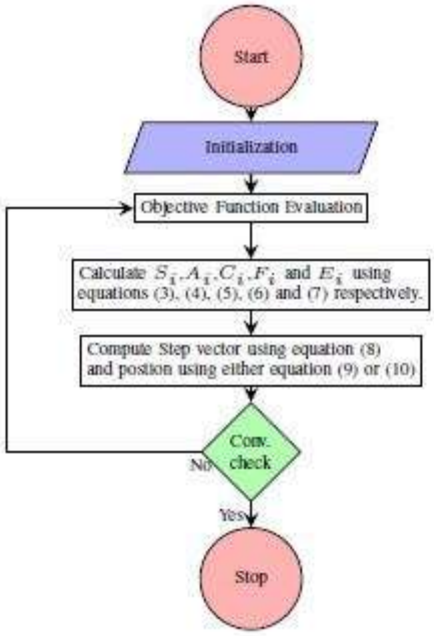

Fig. 1: Dragonfly Algorithm [13]

3. SIMULATION AND RESULTS

3.1 Case Study -1

The proposed method was implemented on PG & E 69 bus distribution system shown in Fig. 2 for optimally place the two DG units with 0.9 lagging power factor in MATLAB environment [14]. PG & E 69 bus distribution system data is drawn from [12].

3.1. 1 Optimal placement of DG

As dragonfly algorithm is a stochastic approach, it was implemented for 10 times on test system. The best sample in terms of objective function (Ploss) is considered as a optimal solution for placement of DG unit. Optimal location and size of the two DG units in PG & E distribution system are presented in Table I. Optimal location and size of the one DG unit in PG & E distribution system are presented in Table II.

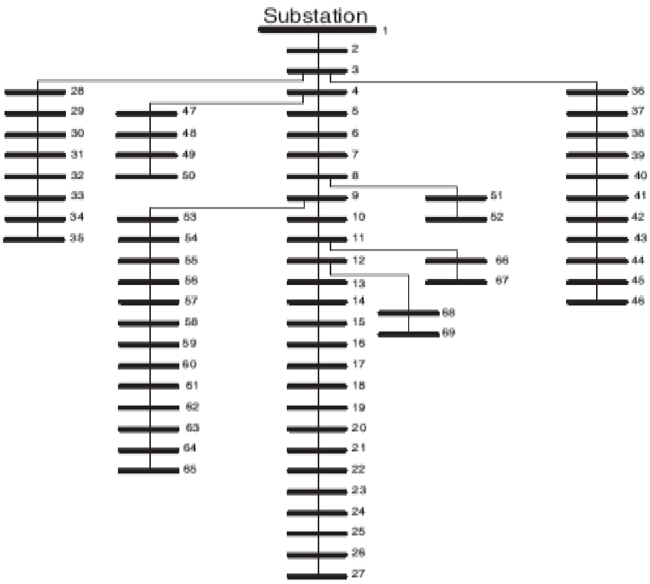

Fig. 2: Single line diagram for PG & E 69 bus radial distribution system

TABLE I: Optimal Location & Size of two DG units

DG	Location	Size (MW)	Losses (MW)	Base case losses (MW)
1	17	0.5623	0.0123	0.225
2	61	1.8951		

TABLE II: Optimal Location & Size of single DG units

DG	Location	Size (MW)	Losses (MW)	Base case losses (MW)
1	61	1.9956	0.0279	0.225

Voltage profile at each bus in PG & E 69 bus radial distribution system with proposed method is compared with base case voltage profile. Base case mean radial distribution system without DG units. From the Fig 3, it has been observed that proposed method improves the voltage profile at each DG bus from base case by optimally placing the single DG unit with optimal size. Similarly, From the Fig. 4, it has been observed that proposed method further improves the voltage profile at each DG bus from base case by optimally placing the two DG units with optimal size.

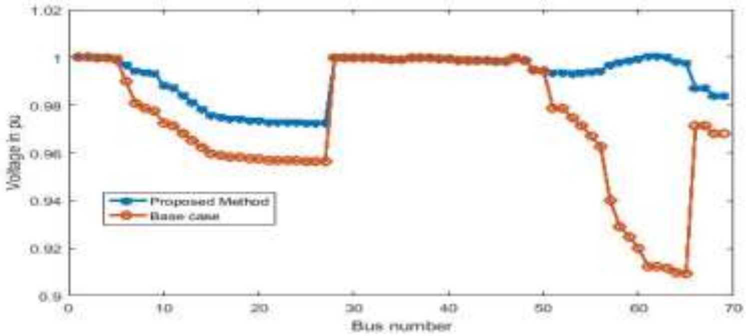

Fig. 3: Voltage profile with proposed method with 1 DG unit

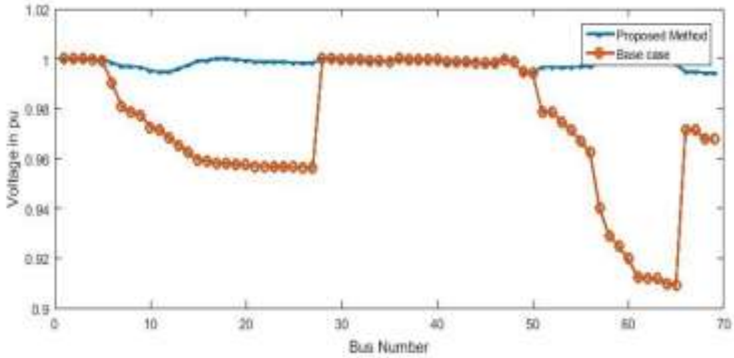

Fig. 4: Voltage profile with proposed method with 2 DG units

Convergence characteristics of Dragonfly algorithm for the problem of optimal allocation of single DG unit and two DG units in give PG & E 69 bus test system are shown in Fig. 5 and Fig. 6 respectively.

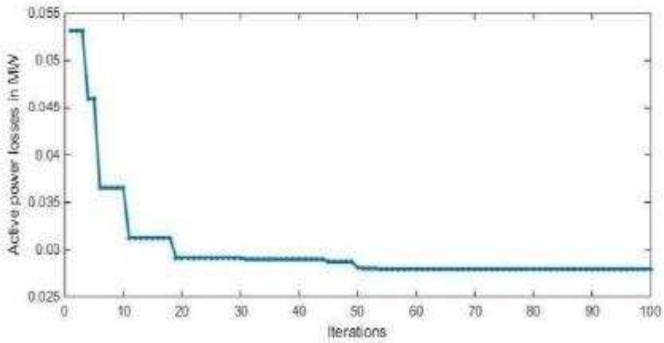

Fig. 5: Convergence characteristics with 1 DG unit

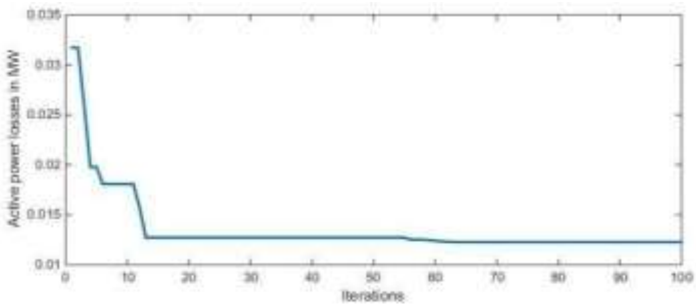

Fig. 6: Convergence characteristics with 2 DG unit

3.1.2 Comparative Studies

The proposed method with dragonfly algorithm is comparing with GA using convergence characteristics as shown in Fig. 7 and Fig. 8. From the Fig. 7 and Fig. 8 observed that DA has fast convergence comparing to GA, and also it gave solution more near to global.

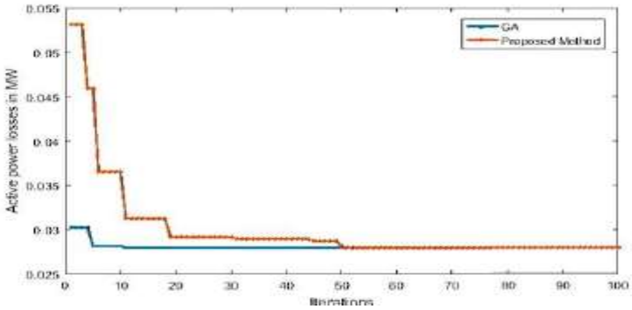

Fig. 7: Convergence characteristics for single DG unit

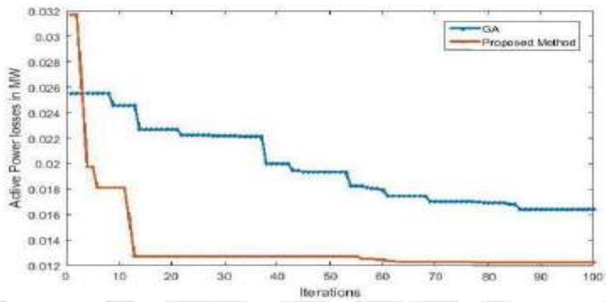

Fig. 8: Convergence characteristics for two DG units

3.2 Case Study -2

The proposed method was implemented on IEEE 15 bus distribution system shown in Fig. 9 for optimally place the two DG units with 0.9 lagging power factor in MATLAB environment [14]. IEEE 15 bus distribution system data is drawn from [12].

3.2. 1 Optimal placement of DG

As dragonfly algorithm is a stochastic approach, it was implemented for 10 times on test system. The best sample in terms of objective function (Ploss) is considered as a optimal solution for placement of DG unit. Optimal location and size of the two DG units in IEEE 15 bus distribution system are presented in Table III. Optimal location and size of the one DG unit in IEEE distribution 15 bus distribution system are presented in Table IV.

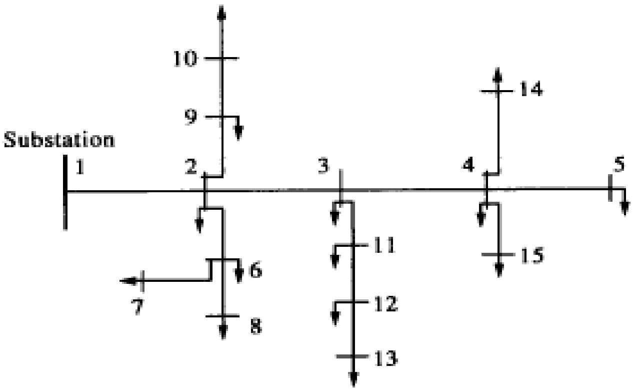

Fig. 9: Single line diagram for IEEE 15 bus radial distribution system

TABLE III: Optimal Location & Size of two DG units

DG	Location	Size (MW)	Losses (MW)	Base case losses (MW)
1	4	0.8431	0.0132	0.0601
2	9	0.4716		

TABLE IV: Optimal Location & Size of single DG units

DG	Location	Size (MW)	Losses (MW)	Base case losses (MW)
1	3	1.0	0.0195	0.0601

Voltage profile at each bus in IEEE 15 bus radial distribution system with proposed method is compared with base case voltage profile. Base case mean radial distribution system without DG units. From the Fig 10, it has been observed that proposed method improves the voltage profile at each DG bus from base case by optimally placing the single DG unit with optimal size. Similarly, From the Fig. 11, it has been observed that proposed method further improves the voltage profile at each DG bus from base case by optimally placing the two DG units with optimal size.

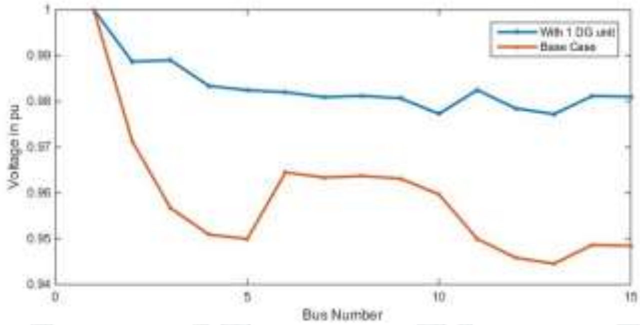

Fig. 10: Voltage profile with proposed method with 1 DG unit

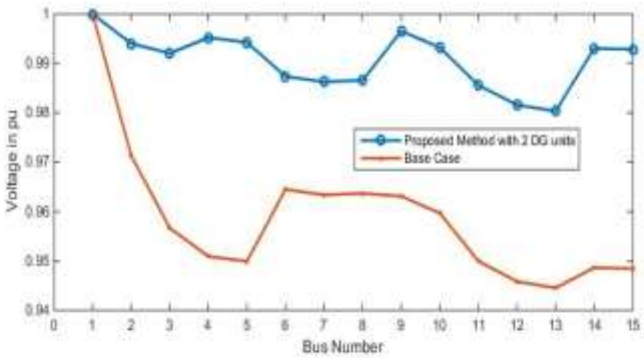

Fig. 11: Voltage profile with proposed method with 2 DG units

Convergence characteristics of Dragonfly algorithm for the problem of optimal allocation of single DG unit and two DG units in give IEEE 15 bus test system are shown in Fig. 12 and Fig. 13 respectively.

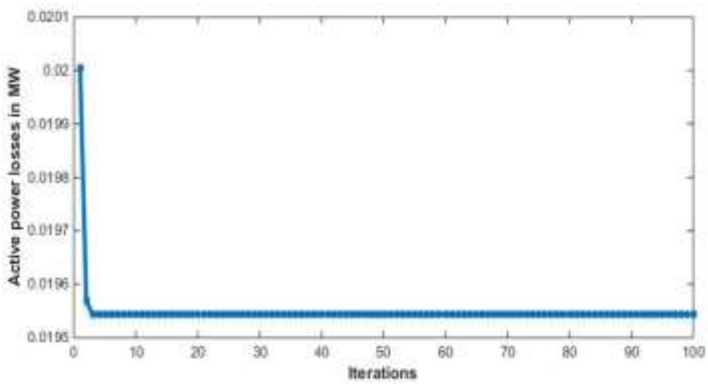

Fig. 12: Convergence characteristics with 1 DG unit

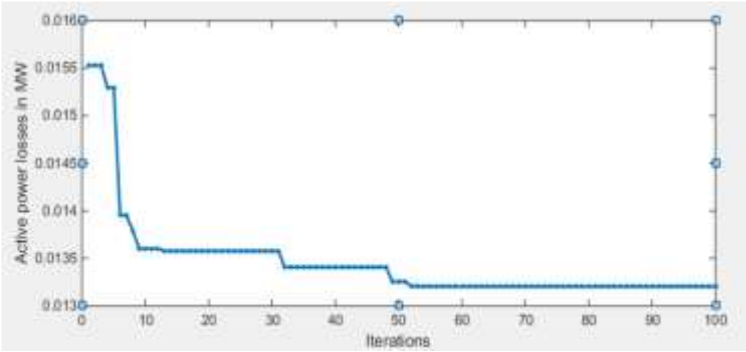

Fig. 13: Convergence characteristics with 2 DG unit

3.2.2 Comparative Studies

The proposed method with dragonfly algorithm is comparing with GA using convergence characteristics as shown in Fig. 14 and Fig. 15. From the Fig. 14 and Fig. 15 observed that DA has fast convergence comparing to GA, and also it gave solution more near to global.

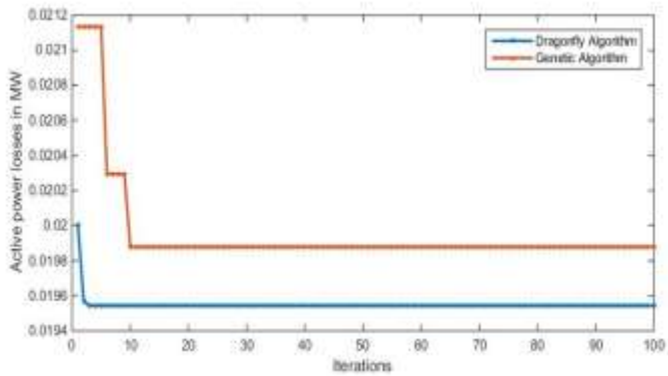

Fig. 14: Convergence characteristics for single DG unit

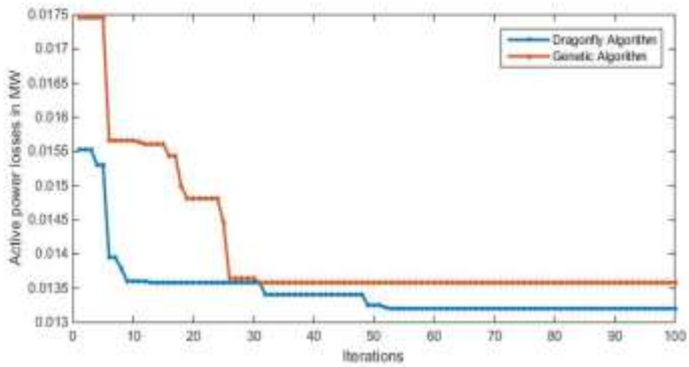

Fig. 15: Convergence characteristics for two DG units

4. CONCLUSIONS

This paper proposed a method for optimal placement and sizing of DG unit in radial distribution system using dragonfly algorithm. Optimization problem was modelled by considering minimization of active power losses as an objective function. Voltage limits at each bus and thermal limit of each line considered as constraints of designed optimization problem for optimal placement and sizing of DG units. The proposed method was implemented on PG & E 69 bus and IEEE 15 bus radial distribution systems.

Based on simulation results, It has been observed that proposed method provides optimal location and size for each DG units such that test systems operates at less active power losses. The proposed method with dragonfly algorithm operates the network with less active power losses in comparison with genetic algorithm (GA).

The proposed method may enable to resolve problems related to distribution network planning and operation. This work can be extended by considering technical objective like emission reduction, reliability improvement and economic objectives like maximization DISCO profit and DG profit. This work can also be extended by integrating the renewable energy sources like photo voltaic (PV) and wind into the distribution network.

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NOMENCLATURE

ΔXt+1 Step vector for dragonflies

Ai Alignment value of dragonfly i

Ci Cohesion value of dragonfly i

Ei Enemy source of dragonfly i

Fi Food source of dragonfly i

Il Current flowing through line l

I_l^{max} Maximum allowable current flowing through line l

loc Location for DG units

n Number of buses

Pg	Active power generation of DG g
P_g^{max}	Maximum active power generation of DG g
P_g^{min}	Minimum active power generation of DG g
Si	Separation value of dragonfly i
Vi	Magnitude of voltage at bus i
V_i^{max}	Maximum bus voltage at bus i
V_i^{min}	Minimum bus voltage at bus i
X^+	Position of food
X^-	Position of enemy
Xj	Position of neighborhood dragonfly
a	Alignment weight
c	Cohesion weight
e	Enemy factor
f	Food factor
N	Number of dragonflies in neighborhood
Ploss	Active power losses
s	Separation weight
X	Position of current dragonfly