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Research Article

Optimal Placement of Embedded Generation in Active Distribution System Using Dragonfly Algorithm

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Abstract: This paper presents a method for optimum position and size of Embedded Generation (EG) in the active distribution network using the Dragonfly Algorithm (DA). The reduction of power losses of the active distribution system was considered to be an objective function. Voltage limits and thermal limits of feeders in the radial distribution system have been considered as a limitation of the optimization problem. The proposed approach has been introduced for the PG & E 69 bus radial distribution network. Reduction of the active power losses of the radial distribution system by selecting the correct location and size of the EG units using the proposed method has been achieved in the simulated results of the test system.

Keywords: Embedded Generation (EG) • Dragonfly Algorithm (DA) • Optimal placement • Active power losses.

1. Introduction

Fig. 1. Benefits due to EG integration [2,13,17]

The integration of Embedded Generation (EG) in the electrical power distribution system has been increased globally due to some of the key benefits that Distribution company will receive as a result of the integration of EG are presented in Fig. 1.

Traditional distribution systems are of a passive nature. These passive distribution systems are transformed into an active distribution system, such as a transmission system, when EG units are integrated[30]. Many technical issues have been considered, such as increasing steady state voltage at the minimum voltage bus and reducing active power losses (APL) for connecting the EG units to the radial distribution system (RDS) [24].

A variety of solutions to the optimum position and size of EG units in the RDS have been published in the literature. Conventional optimization techniques, metaheuristic techniques and artificial intelligence[20] are commonly used to solve this type of optimal placement problem[26]. The main drawback of conventional techniques is that they are generally trapped by local minimum points instead of global ones[3]. Despite of this, modern methods are not designed to address problems with several local minimum points. However, evolutionary algorithms are most efficient in addressing complex real-time problems [10,2].

Table- I: Literature report on optimal placement of EG units in distribution system [21]

Reference	***Bus information***	***Objectives***	***Algorithm***
[11]	6,14,30	Minimization of losses	GA
[7]	33,69	Minimization of losses	GA
[9]	69	Minimization of losses	GA
[23]	33	Minimization of losses	GA
[22]	16,37	Minimization of losses	GA
[27]	69	Minimization of losses	GA
[12]	31	Minimization of losses	PH
[16]	69	Minimization of losses	PSO
[6]	30	Minimization of losses	PSO
[29]	13,33	Multiple objectives	ACO
[1]	69	Maximize voltage limit	ABC
[18]	33,69	Maximize EG capacity	HS
[8]	6,14,30	Maximize EG capacity	PH
[15]	11/0.4kV	Reliability improvement	MCS

Many studies have addressed this problem, known as the optimum position and size of EG units in the distribution network, using meta - heuristic optimization techniques such as genetic algorithm (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Harmony Quest (HS), Monte Carlo Simulation (MCS) and Particle Heuristic (PH), as described in Table I..

All the literature works presented in Table 1 make a significant contribution to the Optimal positioning of EG units using metaheuristic algorithms. However, these have certain limitations, such as premature convergence and results, which are not guaranteed.

In this article, the Dragonfly Algorithm (DA) is being used for the first time to solve the optimization problem , i.e. the optimum distribution of the EG unit to the RDS. The optimisation of the APL of the delivery system was investigated as an objective function. Decision factors are known to be the position of the amount of busses in the delivery network and the scale of the EG in terms of generating power. Voltage limits for each bus and thermal limits for each line in the distribution system have been considered as limitations in this optimization problem. In this study EG units which can be models as PQ like combined cycle gas turbines (CCGT), gas internal combustion engines (G-ICE) and diesel internal combustion engines (D-ICE) are used.

The remaining portion of the paper was structured as follows : Section II explains the research design and methodology, Section III discusses the simulation performance of the proposed approach, and Section IV summarizes the conclusions of this article.

2. Methodology

The optimization model for the optimum allocation of EG units in the RDS was planned to reduce the APL. The objective function of this optimization model has been considered as shown in equation (1) and the shortcomings are described as shown in equation (2).The above mentioned optimization problem was resolved in this paper using the Dragonfly Algorithm[14]

Minimize Ploss (1)

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

A. Dragonfly Algorithm (DA)

There are drawbacks to current conventional algorithms, such as a highly sensitive starting point, often converging to an optimal local solution. Complex problems were solved by biologically inspired algorithms[25][31]. Dragonfly Algorithm (DA) was one of the bio-inspired algorithms that developed based on dragonflies' swarming behavior.

There are two types of swarming that are static and dynamic. Dragonflies form small groups and move forward and backward over a small area to hunt for other flying preys during a static swarm. Whereas, during a dynamic swarm, a large number of dragonflies move in one direction over a long migration distance. Dynamic swarming with high alignment and low cohesion is related to the exploration phase, and low alignment and high cohesion static swarming can be related to optimization exploitation. The five major factors included in dragonflies' swarming are isolation, alignment, cohesion, food addiction, and detachment from the opponent. The above factors have been mathematically modeled in equations (3), (4), (5), (6) and (7) respectively.

$$S^i = -\sum_{i=1}^{M} Y - Y_i \quad (3)$$

$$A_i = \frac{\sum_{j=1}^{M} Y_j}{N} \quad (4)$$

$$C^j = \frac{\sum_{j=1}^{M} Y_j}{N} - Y \quad (5)$$

$$F^i = Y^+ - Y \quad (6)$$

$$E^i = Y^- + Y \quad (7)$$

As per dragonfly algorithm, dragonflies are updated using equations (8). If neighborhood exists, dragonflies will be updated using equation (9) otherwise using equation (10). The full flowchart to address the optimization problem using the dragonfly algorithm is shown in Fig. 2.

$$\Delta Y_{t+1} = (sS^i + aA^i + cC^i + fF^i + eE^i) + \omega \Delta Y_t \quad (8)$$

$$Y_{t+1} = Y_t + \Delta Y_{t+1} \quad (9)$$

$$Y_{t+1} = Y_t + Levy * Y_t \quad (10)$$

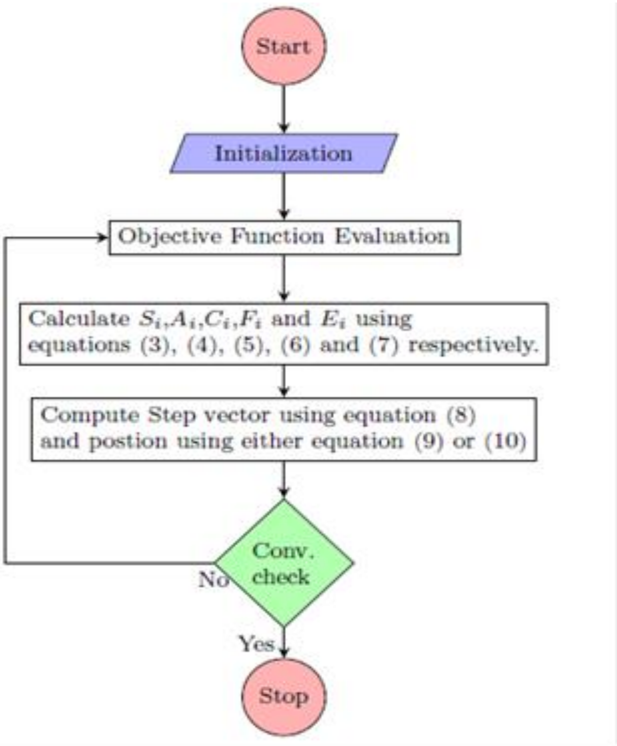

Fig. 2. Dragonfly Algorithm [14]

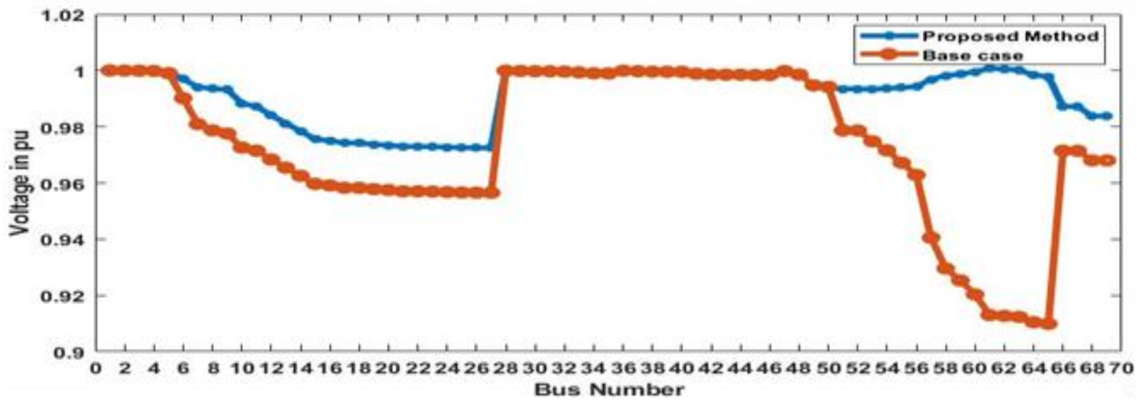

Fig.4. Voltage profile with proposed method

3. Analytical Study

The proposed method was implemented in the PG & E 69 bus distribution system as shown in Fig. 3 to optimally place two EG units with 0.9 lagging power factor under the MATLAB environment[19]. The data for the PG & E 69 bus distribution system is derived from[28].

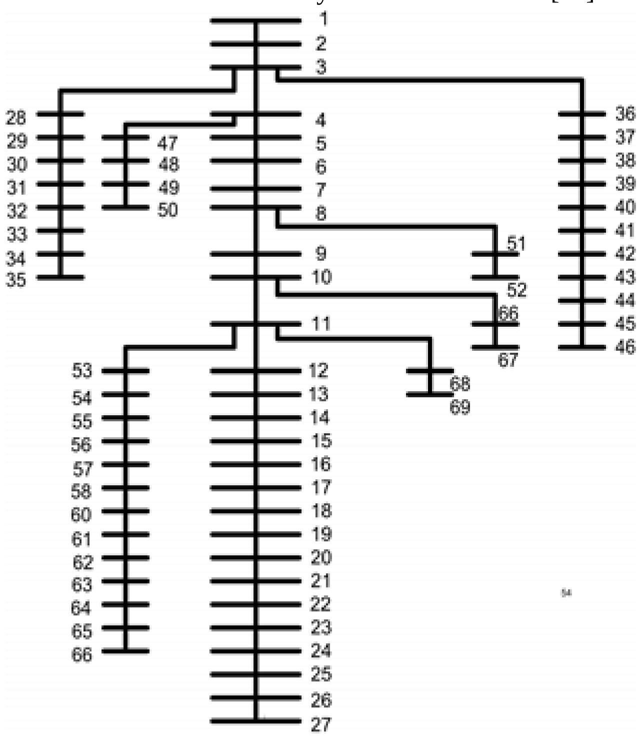

Fig. 3. PG & E 69 bus distribution system [28]

A. Optimal placement of EG

Since the dragonfly algorithm is stochastic in design, it has been implemented ten times. The best sample for minimum active power losses is considered an optimal solution for EG unit placement. In Table II, two EG units are presented as optimal places and capacities in PG & E distribution systems.

The voltage profile of each bus in the PG & E 69 bus RDS with the proposed method is compared to the base case voltage profile. Base case means a RDS without an EG unit being considered. It's been seen from the fig. 4 that the proposed method improves the voltage profile of each EG bus from the base case by optimally positioning the EG units of the optimum size.

Table- II: Optimal Location & Size of EG units

EG	*Location*	*Size (kW)*	*Losses (kW)*	*Base loss (kW)*
1	61	1000	27.9	221.8
2	61	1000		

The performance of the dragonfly algorithm for the optimum location of the EG problem is verified in the stochastic environment in terms of mean and standard deviation. Average and standard deviations of APL over 10 simulations are reported in Table III. The stochastic performance of the dragonfly algorithm is checked for standard deviation. Standard deviation of objective function is active loss of power over 10 simulations equal to zero as shown in Table III. This shows that the dragonfly algorithm always provides a solution that is close to global

Table- III: Stochastic Analysis of proposed approach

Simulations	***Active power loss in kW***			
	Best	***Worst***	***Mead***	***Std.***
10	27.9	27.9	27.9	0

The convergence characteristics of the Dragonfly algorithm concerning the problem of optimal allocation of EG units in the PG & E 69 bus test system are shown in Fig. 5.

Over 100 iterations of DA algorithm, the algorithm identifies 4 combinations for EG locations as presented in Table IV, finally stabled at 4th combination that is both units at bus 61.

Table- IV: Various combinations of EG locations verified by Dragonfly Algorithm

EG1-Location	EG2-Location	Loss (kW)
57	57	104.6
62	61	54.7
61	64	45.8
61	61	27.9

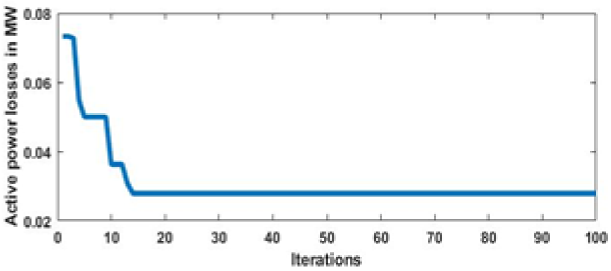

Fig. 5. Convergence characteristics of dragonfly algorithm

B. Comparative Studies

The proposed method is validated by comparison with other evolutionary techniques such as GA[4] and PSO[5]The relation of the proposed approach to GA and PSO for probabilistic parameters is seen in Table V. Table V shows that the dragonfly algorithm performs well over the GA and PSO. The P-value is less than 0.05 for both GA and PSO. The P-values shown in Table V represent a significant difference between PSO and DA, GA and DA.

Table- V: Comparison of proposed approach with GA [4] and PSO [5] in stochastic environment

Simulations	***Method***	***Active power loss in kW***				***P-Value***
		Best	***Worst***	***Mead***	***Std.***	
10	GA[4]	46.1	95.1	68.6	0.0147	$6.75X10^{-8}$
	PSO [5]	28.6	49.1	39.5	0.0089	0.00065
	Proposed Method	27.9	27.9	27.9	0	NA

The comparison of the dragonfly algorithm's convergence characteristics with GA and PSO is shown in Fig. 6. It's seen from Fig. 6 that the DA has a fast convergence compared to the PSO and the GA. In addition , the proposed method provided a solution that was closer to the global optimum.

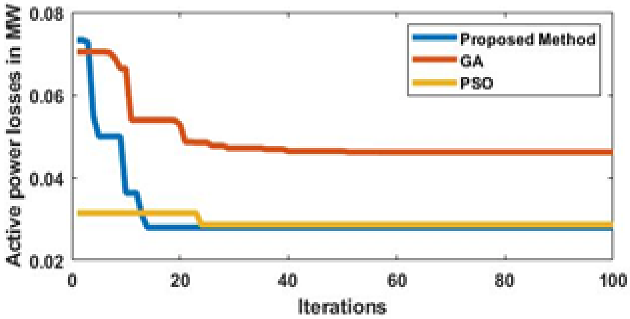

Fig. 5. Comparison of proposed method with GA and PSO interms of convergence charectarstics .

4. Conclusion

This paper proposed a method for optimal placement of the EG unit in the RDS using the dragonfly algorithm. The optimization problem was modeled by considering the objective function of minimizing APL. Considered the voltage limits of each bus and thermal limits of each line as a constraint on the design of the optimization problem for the optimal positioning of the EG units.

The proposed method was applied to the PG & E 69 bus RDS. Based on the simulation results, it has been observed that the proposed method provides an optimal location and size for each EG unit, such that the PG & E 69 bus system operates with less APL. The proposed dragonfly algorithm method operates a network with less active power loss compared to GA and PSO algorithms. The performance of the proposed DA method is compared with GA and PSO in the stochastic environment and observed that DA performs well over GA and PSO. This work can also be extended by integrating renewable energy sources such as photovoltaic (PV) and wind into the distribution network.

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