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Minimization of Cost by Simultaneous Placement of Multi-DGs and Capacitors in Distribution System Using Hybrid Optimization

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Abstract: *At present continuous effort is made to minimize the real power loss in distribution system by simultaneous placement of Distributed Generation (DG) and capacitor. The selection of proper location and size of DG and capacitor is the important factor in reducing the line loss. In this work, hybridization of Genetic Algorithm (GA) and Artificial Bee Colony (ABC) algorithm is proposed for finding optimal location and size of multi DGs and capacitors in radial distribution system. The main objective of this work is to reduce the cost of system by optimal placement of multi DGs and capacitors which in turn reduce the real power loss. This hybrid algorithm is tested on IEEE 33 and IEEE 69 bus radial distribution systems. The result shows that cost of the system is reduced by the help of this algorithm.*

Keyword: *Capacitor banks; Distributed Generation; Hybrid optimization; loss reduction; operating cost; Radial distribution system.*

1. INTRODUCTION

Distributed Generation (DG) is a small-scale electricity generation unit, which supplies electricity directly to the load centre. It is the new approach in power system which helps in meet out the increasing energy demand [1]. The distribution system plays vital role in real power line loss so the increase in use of Distributed Generation in this system minimizes the line loss. This new approach has some major impact on power flow, voltage profile, stability, continuity of supply, short-circuit level and quality of power supply for customers and electricity suppliers.

In past year's only capacitors plays major role in reduction of line loss. But present days Distributed Generation is widely used because they utilize renewable resources and also it delivers both real and reactive power. In this work multiple DGs and capacitors are simultaneously placed to minimize real power line loss in distribution system. There are many analytical and heuristic approach for finding optimal location and size of DG and capacitor.

In [2-4], optimal location and size is determined by analytical method to minimize total power losses in primary distribution system. Based on genetic algorithm (GA) [5], optimal location and size of DG is determined for maximizing the benefit/cost ratio.

Benefit is measured by the reduction of losses and cost is calculated by the investment of DG. Nowadays, many Meta heuristics optimization methods provide efficient utilization of benefits of distributed generation in radial distribution system. Moradi [6] proposed combined method for minimizing losses, improving voltage profile and stability of the system. GA and particle swarm optimization (PSO) methods are used to find suitable location and size of DGs. Optimal location and size of multiple DG units are determined using an improved analytical (IA) [7] method to minimize network losses. In [8], PSO based optimization is used to allocate multiple type of single DG to reduce loss and results compare with analytical

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method. Two phase method is used to minimize the system losses and maximize the system stability in [9]. Loss sensitivity method is used to find potential nodes for installation of DGs and simulated annealing is implemented for determining the optimal bus and size of DGs. Memetic algorithm [10] is used to optimal allocation of DG and capacitor simultaneously for the improvement of voltage profile and reduction of losses in RDS. Imperialist competitive algorithm (ICA) hybridized with GA [11] is proposed for simultaneous placement of DG and capacitor in radial distribution system for minimization of losses and to improve the voltage profile. In [12], a hybrid optimization based on analytical method and PSO is proposed for placement of multiple types of multiple DGs to reduce the losses in distribution system.

In this proposed work, a new hybrid approach is proposed by combining two algorithms namely, Genetic Algorithm (GA) and Artificial Bee Colony Algorithm (ABC) for finding optimal location and size of DGs and capacitors simultaneously. This hybrid optimization algorithm is used to minimize the cost of the system by installing multi DGs and capacitors simultaneously in two different distribution systems.

This manuscript contains the sections such as introduction, problem formulation, proposed methodology, test system, results and discussion, conclusion and references.

2. PROBLEM FORMULATION

The objective function for minimization of cost is formulated as

$$Min\,Cost = CE^{ss}_{DG\,\&\,Cap} + CPDG + CCAP \quad (1)$$

2.1 Cost of Energy Received from Substation with DG and Capacitor

$$CE^{ss}_{DG\,\&\,Cap} = \sum_{y=1}^{nyr} PW^{y} P^{WDG}_{SS} . C_{SS} . T \quad (2)$$

2.1.1 Total Real Power Received from Substation

$$P^{WDG}_{SS} = P_D + P^{WDG}_{L} - P_{DG} \quad (3)$$

Where, P_D is the real power demand, P_L^{WDG} is the total real power loss with DG, P_{DG} is the total real power injected by DG and nyr is planning period.

2.1.2 Present Worth Factor

$$PW = \frac{1 + InfR}{1 + IntR} \quad (4)$$

Where, $IntR$ is interest rate and $InfR$ is the inflation rate.

2.2 Cost of Real Power Produced by DG

$$CP_{DG} = P_{DG} . C_{DGinv} + P_{DG} . \sum_{y=1}^{nyr} PW^{y} . C_{DGo\&m} . T \quad (5)$$

Where, investment cost of DG C_{DGinv} is taken as 318,000 \$/MW, operation and maintenance cost of DG $C_{DGo\&m}$ is 36\$/MWhr and C_{SS} is market price of energy received from substation and the price is taken as 49\$/MWhr [11].

2.3 Cost of Reactive Power Produced by Capacitor

$$CCAP = \sum_{i=1}^{n_c} K_{cni}\, Q_{cni} + K_{dni} \quad (6)$$

Where, K_{cni} is the cost of reactive power injected by capacitor (\$/Kvar/year) at bus n_i, Q_{cni} is the reactive power output of capacitor bank at bus n_i and K_{dni} is the fixed cost of capacitor (\$).

The objective function is subjected to following constraints:

1. Power balance constraint:

$$P_{DGi} = P_{Di} + P_{Loss} \quad (7)$$

2. Voltage limits:

$$V_{i\min} \le V_i \le V_{i\max} \quad (8)$$

3. Line Power Flow limit:

$$S_{ij} \le S_{ij\max} \quad (9)$$

4. DG Constraints:

$$P_{DGi\min} \le P_{DGi} \le P_{DGi\max} \quad (10)$$

$$p.f^{\min}_{DGi} \le p.f_{DGi} \le p.f^{\max}_{DGi} \quad (11)$$

$$Q_{DGi} = P_{DGi} \tan\left(\cos^{-1}\left(p.f_{DGi}\right)\right) \quad (12)$$

5. Capacitor Constraint:

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$$\sum_{i=1}^{n_c} Q_{ci} \le Q_t \tag{13}$$

Where, V_i is the voltage magnitude of bus i, V_{min} and V_{max} are minimum and maximum limit of voltage in buses respectively. $S_{ij\,max}$ is maximum limit of load flow between line i and j.

3. PROPOSED METHODOLOGY

In this work , a new hybrid method of optimization based on GA and ABC is proposed to find optimal location and size of multiple DGs and allocation of capacitors in radial distribution system.

3.1 Genetic Algorithm

Genetic Algorithm (GA) [13] has population of candidates to search several areas of a solution spaces and works on natural selection process.
Each individual is consider as a potential solution of a given problem and encoded binary string as chromosome.

With randomly initialization of population, fitness values are evaluated. The generation of new population is carried out through sequential operations such as selection, cross over and mutation.

Steps involved in Genetic Algorithm:

1) *Initialization:*

The initial population is randomly generated depending on nature of problem and the desired size of problem.

2) *Selection:*

Best individual solutions are selected using fitness-based process. The quality of the solution is given by fitness function. The fitness function is always problem dependent.

3) *Genetic Operators:*

The next step is to generate a new population solution by performing combination of crossover and mutation operators in selected pair of population. This process continues until a new population of desired size is generated.

4) *Termination:*

This process is repeated until a termination condition is reached. Common termination conditions are

a) Fixed number of generation is achieved.

b) Allocated commutation time/memory reached.

c) There is no improvement in solution even after reaching desired number of iteration.

d) If solution satisfies the stopping criteria.

3.2 ARTIFICIAL BEE COLONY ALGORITHM

The artificial bee colony algorithm [14] is one of the meta-heuristic optimization technique defined by Karaboga in 2005.

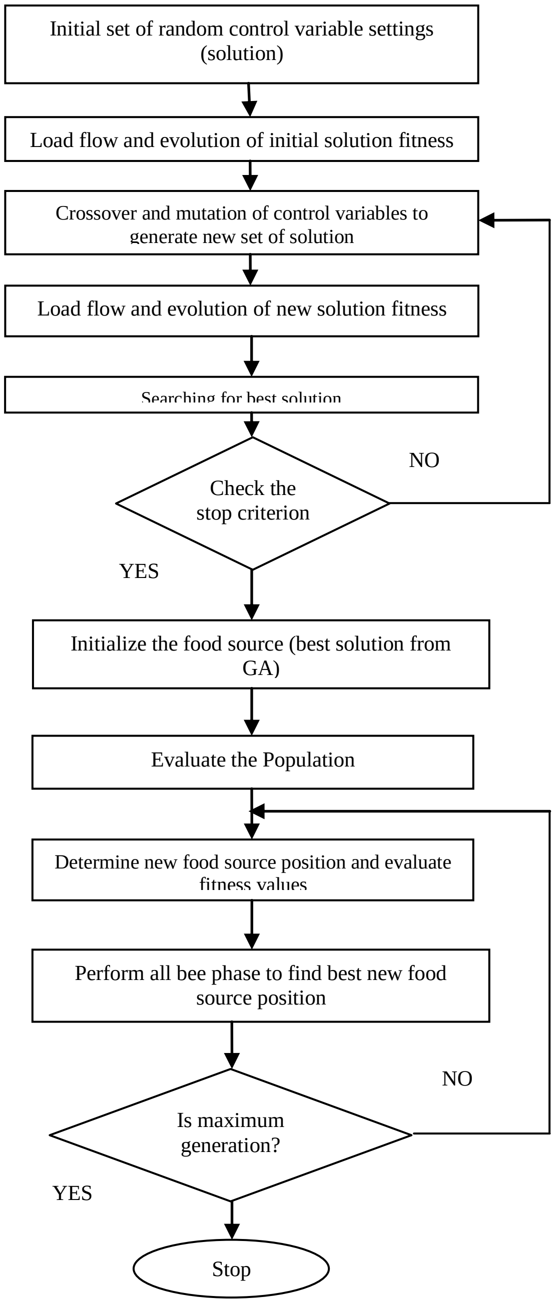

Figure 1 Flowchart for GA-ABC

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The ABC algorithm is derived from honey bee foraging behaviour. Colonies of honey bees have a structured social organization. In the bee colony, the honey bees are classified as: employed bees, onlooker bees and scout bees.

Each employed bee exploits one specific food source (solution), and then returns to the hive to give the information about that food source with the other bees through specialized waggle dances. This dance shows the quality of the food source. In other words, all information is available on the dance floor.

The onlooker bees watch the dance of employed bees to make decisions about which food source produce best source. The indirect communication between bees by dance allows for good food sources to attract more onlooker bees. If the food source visited by bees is not improved, then the source is abandoned and the employed bee becomes a scout.

Every bee colony has scout bees to avoid local optima solution whenever a source is exploited fully. They do not have any guidance while looking for food. Scout bees carry out a random search to explore the non improved food source to find new food source locations (solution).

3.3 GA-ABC Algorithm

In this approach, algorithm is run until the stopping criterion is met. Here, the stopping criterion is maximum number of iterations. Initially, GA first executed to find optimal solutions. Then, the optimal values of individuals generated by the GA are given to the ABC as its starting point. Then ABC is run to find the optimal power values and the minimum cost of the system.

Pseudo-Code:

- Run GA.
- Generate optimal values for all individuals.
- Pass these individuals to ABC as starting points.
- Run ABC till stopping criterion is met.

The procedure for proposed method is explained in Figure1.

4. TEST SYSTEM

The proposed methodology is tested on IEEE standard 33and IEEE standard 69 test systems shown in Figure 2 and Figure 3. This system consist of 33 bus, 32 branch radial distribution system with the total load of 3.7 MW and 2.3 MVAr [15]. The active power loss in the system before connecting DG and capacitors is 210.07kW.

The second test system contains 69 buses and 68 branches radial system with total load of 3.8 MW and 2.69 MVAr [16-17]. The active power loss in the system before installing DG and capacitors is 224.59kW.

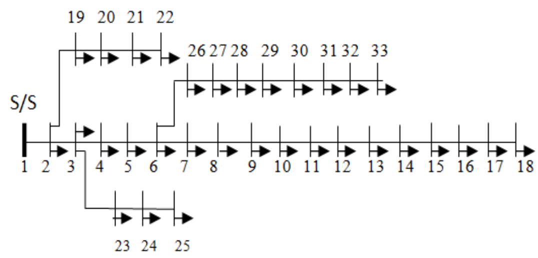

Figure 2 IEEE 33 Bus Radial Distribution system

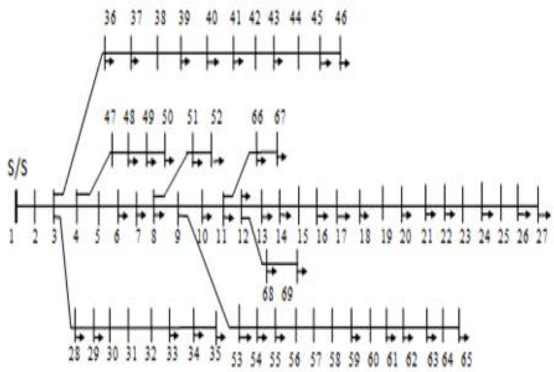

Figure 3 IEEE 69 Bus Radial Distribution system

5. RESULTS and DISCUSSION

The forward backward algorithm is used for evaluating the losses in the system before installing the DG and capacitors. Then, proposed hybrid approach is applied to find simultaneous placement of DGs and capacitors for minimization of cost in the IEEE33 bus system and IEEE 69 bus system. The result obtained from this proposed method is compared with the results of ABC and GA.

In this work, number of DG and Capacitor is three and planning period is for 5years.Before installation of DG and Capacitor the real power demand is satisfied by purchasing real power from the substation by this real power loss of the system is high. The main aim for installation of DGs and Capacitors in radial distribution is to reduce the cost of system because real power demand is now provided by DG and real power loss is reduced by connecting DG nearer to load centre.

The cost value for different methods in the 33-bus system with DGs and capacitors is given in Table 1. It contains the value for real power (kW) and power factor (pf) of three DGs and reactive power (kVAr) delivered by three capacitors. From this table it is clear that the cost of system when simultaneous placement of DGs and capacitors ($7119176) is lower than other methods. It also shows that real power loss (10.54 kW) is also lower than other methods.

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TABLE 1 COMPARISION OF COST VALUES WITH OTHER METHODS FOR IEEE 33 BUS SYSTEM

Method	Location and Size of DG			Location and Size of Capacitor		Cost in $(x10^6)$	Real Power Loss in (kW)
	Bus	kW	pf	Bus	KVAr		
GA	13 30 25	831.55 1008.36 541.19	0.987 0.748 0.893	23 15 26	350 200 250	7.12496	13.32
ABC	24 14 30	1071.90 745.53 1022.59	0.915 0.956 0.744	8 29 21	300 50 50	7.11966	10.80
GA/ABC	30 13 24	1012.74 814.58 1051.02	0.845 0.952 0.912	7 32 17	300 250 50	7.11917	10.54

TABLE 2 COMPARISION OF COST VALUES WITH OTHER METHODS FOR IEEE 69 BUS SYSTEM

Method	Location and Size of DG			Location and Size of Capacitor		Cost in $(x10^6)$	Real Power Loss in (kW)
	Bus	kW	pf	Bus	KVAr		
GA	18 49 61	658.36 607.07 1743.10	0.925 0.834 0.830	51 48 11	250 300 150	7.27472	4.85
ABC	11 18 61	499.76 367.99 1666.55	0.980 0.857 0.810	49 51 14	850 350 100	7.27262	3.82
GA/ABC	11 61 21	511.74 1677.36 349.96	0.858 0.814 0.921	50 61 68	550 100 50	7.27165	3.37

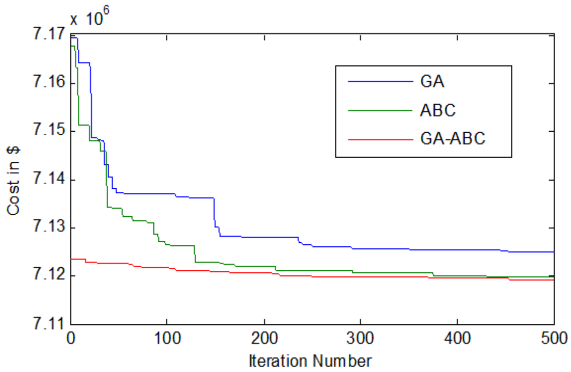

Figure 4 Comparison Graph for Cost Reduction between Various Methods in IEEE 33 bus system

Figure 4 shows comparison result for cost reduction between ABC, GA and GA/ABC and show the effectiveness of proposed method. Figure 5 shows comparison result for cost reduction between ABC, GA and GA/ABC and represents the effectiveness of proposed method for IEEE 69 bus system. Figure 6 represents the voltage profile improvement in distribution system by optimal location and size of DGs and capacitors in IEEE 33 standard radial bus system. The results show that the voltage profile of proposed method is better than voltage profile of other methods in the same distribution system.

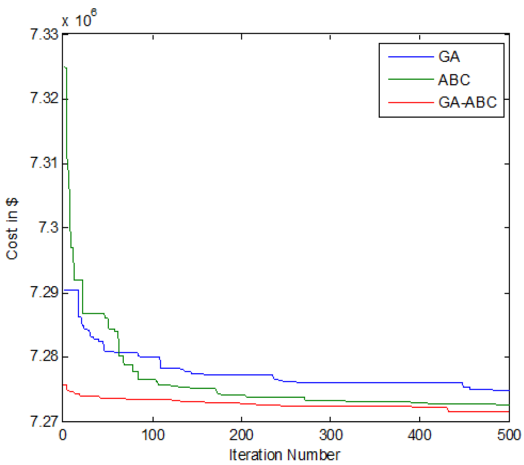

Figure 5 Comparison Graph for Cost Reduction between Various Methods in IEEE 69 bus system

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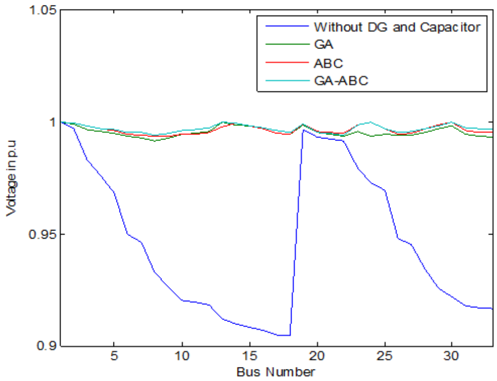

Figure 6 Comparison Graph for Voltage Profile Improvement between Various Methods in IEEE 33 bus system

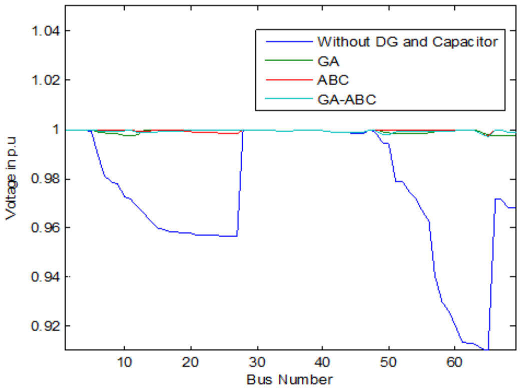

Figure 7 Comparison Graph for Voltage Profile Improvement between Various Methods in IEEE 69 bus system

Figure 7 represents the voltage profile improvement in distribution system by optimal location and size of DGs and capacitors in IEEE standard 69 radial bus system. The results show that the voltage profile of proposed method is better than voltage profile of other methods in the same distribution system.

The cost value for different methods in the 69-bus system with DGs and capacitors is given in Table 2. It contains the value for real power (kW) and power factor (pf) of three DGs and reactive power (kVAr) delivered by three capacitors. From this table it is clear that the cost of system when simultaneous placement of DGs and capacitors ($727165) is lower than other methods. It also shows that real power loss (3.37 kW) is also lower than other methods.

6. CONCLUSION

In this paper new hybrid method is proposed to solve the cost reduction by finding optimal location and size of multiple DGs and capacitors simultaneously in 33 and 69 bus distribution systems. In this method, GA and ABC algorithm is combined to find optimal location and size of multi-DGs and capacitors. Real power loss reduction and voltage profile improvement is achieved by this method. Also result of combined GA-ABC algorithm is compared with results of separate GA and ABC techniques which show the efficiency of the proposed method in terms of loss reduction and economic savings.

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