# Supervised evolutionary programming based technique for multi-DG installation in distribution system

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## Article Info

## ABSTRACT

Installing DG in network system, has supported the distribution system to provide the increasing number of consumer demand and load, in order to achieve that this paper presents an efficient and fast converging optimization technique based on a modification of traditional evolutionary programming method for obtain the finest optimal location and power loss in distribution systems. The proposed algorithm that is supervised evolutionary programming is implemented in MATLAB and apply on the 69-bus feeder system in order to minimize the system power loss and obtaining the best optimal location of the distributed generators.

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## 1. INTRODUCTION

In recent decades, distribution network has been developed due to meet the increasing number of consumers power demand and load [1]. This increasing demand has become the most important challenge to the power system in supply the power and load to consumers [2]. But still there are a few side effects that cause voltage drop, increased losses, power loss and load imbalance in the distribution system [1]. The electricity demand is expected to gradually increase by 28% from 2011 until the end of 2040, in 2011 the power growing from 3,839 billion kWh until reach 4,930 billion kWh in 2040 [3]. Power utilities are responding to meet this increasing demand during the period. Briefly power system can be subdivided into three major parts that is generation, transmission, and distribution. In the generation section, the electric power was generated and the voltage was stepped up to high voltage. Then the transmission network transfers the high voltage from generating station to the distribution system which ultimately supplies the load. Before the transmission network connected to the distribution system, the voltage was stepped down to medium and low voltage. Lastly the distribution network distributed the low voltage to the end users [4]. However the low voltage in the distributed system has led to high power losses due to low voltage with having a high current comparable to high voltage network, this cause the distributed system suffers the poor voltage profile and increasing cost power [5].

Basically the total power generated at the generation unit is not the same amount of total power consumed by the end users of the distribution system, the amount of the total power slowly dropped during power dispatch [6]. In developing countries, the amount of power loss in the distribution network is about 20% of total power generated loss due to the I2R in the network, this cost millions of dollars wasted every year [7]. The power loss in a distributed system can be categorized into two losses: real power and reactive power, but the effect of active power loss is the most important because it reduces the efficiency of power transfer and deteriorates the voltage profile [5]. To overcome this problem the most cost-effective and economical solution is by installing the distributed generation (DG) in the distribution network [2]. In having, distributed generation (DG) installing to the distribution system help to reduce the network losses, supply power and improving the voltage profile of the distribution system [8].

DGs can also be known as 'Embedded Generations' or 'Disperse Generations' which capable generates power in the range of 3–10,000 kW from renewable energy [9]. DG has also define as the generating plant that generated maximum power capacity of less than 100 MW and connected to the distribution network, according to the CIGRE [10]. However, DG commonly define as electric power source connected directly to the distribution network or on the consumer side of the meter range from a few kWs to a few MWs [11]. The existing of Distributed generation (DG) in electric power system has become an important part in the distribution network as it reinforces the main generation system in covering the growing demand today [12]. Friendly environmental factor such as environmental pollution, had led the increase of DGs unit to be used for establishment of new transmission lines and technology development resources [13]. Unlike the main power stations, DG can be connected or disconnected easily from the network besides providing higher flexibility to the system [12]. DG serves as integrating network for household and industrial units with heat and power generation capacities to achieve utility self-sufficiency and sharing of excess utilities [14].

As the distributed generation (DG) is often used in the distribution network had brought the development of various types of DG such as renewable and non-renewable energy source [15]. The growing of environment concern led to the use of renewable energy source DG such as solar, wind, geothermal, biomass, bio gas and hydroelectric power, which expects a growth of 183% of the installed power for the period between 2009 and 2016. By using the renewable distributed generation, give many benefit such as reduce the consumption of fossil fuel, the greenhouse gas emission and also help reduce noise pollution [14-16]. However, there are three main types of DG, that is real power DG or unity power factor DG (UPF-DG), reactive power DG and both real and reactive power DG is also known as lagging power factor DG [17]. Besides that, DG also can be categorized on the basis of power rating such as for micro-distributed generation the rating range is between 1W to 5 kW, small distributed generation the rating goes from 5 kW to 5 MW, medium distributed generation is 5MW to 50 MW and for a large distributed generation the rating is from 50MW to 300 MW [18]. The fundamental purpose having DG in the distribution network is because DG able to yield many benefit to be achieve such as voltage profile improvement, reduced lines losses, increased security for critical loads, grid reinforcement, and reduction in the on-peak operation cost [19]. Besides that by having DG technology will also lead to flexibility in electricity price and the system performance [20]. By having distributed generation (DG) into the system, the system can gain many advantages such as suspend the upgrade of an existing system, reduce peak, minimize power losses, cheap maintenance cost, excellent reliability, power quality improvement, possibility to exploit CHP generation, fulfill the increasing demand without requirement spendthrift investment and shorter construction schedules [21]. Regard of that, to efficiently obtain these benefits, it is essential to determine the optimal placement of DG units in the distribution system so that the system can become more excellent in performance [22].

As to contribute the distribution network and enchance the network performance, many research have focused on developing fast and effective technique to reduce the power loss. Some of the technique is by using analytical approaches, numerical method, and heuristic algorithm [23]. According to Merlin and Back, heuristic method provides the sequential opening algorithm. However Civanleretal, has proposed other heuristic method that is branch exchange algorithm. Although plainness is the advantage of this heuristic method, but the nature of the heuristic method itself are avaricious and provide results without considering the whole problem [24]. The optimization technique like Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Artificial Bee Colony Algorithm (ABC), and Modified Teaching-Learning Based Optimization (MTLBO) is the technique that most of researchers have focused on developing methodologies for minimizing power loss and assumption of DG location [23, 25-26]. Evolutionary algorithm such as Genetic Algorithm is commonly used in optimization. Genetic Algorithm (GA) usually operates based on population of capability solution applying the fundamental of the fittest to provide better approximate result [27]. Other than, Genetic Algorithm (GA), Particle Swarm Optimization (PSO) also one of the mainly technique that been in the optimization [28]. PSO algorithm is a technique for optimizing

complex numerical functions based on simulating the natural behavior of bees and PSO has no overlapping and mutation calculation. PSO take the most optimist information and spread it to other particle, wish to result the speed and the research is fast [29].

In order to improve the location and power loss of DG units, the development of supervised evolutionary programming based technique for multi-DG installation in distribution system is being presented. This algorithm based on traditional evolutionary programming and an orientation table consists of number intervals and the corresponding best location for each interval. This technique guarantees of reaching the optimal solution with less effort and with rapid convergence. The proposed algorithm is implemented in MATLAB and tested on the 69-bus feeder in order to improve the optimal location of DG and minimize the power loss.

## 2.   RESEARCH METHOD

*Algorithm*

Supervised evolutionary programming is proposed in order to ensure of reaching the optimal solution with rapid convergence and less effort. Figure 1 shows the flow chart of the supervised evolutionary programming and it is discussed in the following step by step procedure.

a.   Pre-optimization
−   In this section, the load increment is regulate from 1Mvar to 5Mvar with the increment of 1Mvar for bus 6, based on load increment test. It also known as initial/unstable condition before optimization process.
b.   Orientation table
−   Orientation table is formulated by dividing the DG active power range $0 \leq Pg \leq Pg_{max}$ to n equally divisions.
−   For each of the divisions the best location is randomly estimated by setting the DG active power to the middle values of each division.
−   Each division will find the location that achieve the minimum active power loss.
c.   Initialization
−   In this section, DGs locations, X1, X2, and X3 are generated randomly.
−   The range of the location is set between 1 to 68 to determine as location for 69bus system.
d.   Fitness 1
−   Collecting suitable variables of location and power based on the 20 accepted data from the initialization process.
−   Known as parent data
e.   Mutation
−   Operator use to breed offspring/children based on parents produced from generation of N(a,d) Gaussian distributed.
−   A new set of offspring/children are generated based on acceptable parent data from fitness 1.
−   The value of P1, P2, and P3 is used for the mutation process.
−   Equation for mutation as following:

$$x_{i+m,j} = x_{i,j} + N\ (0, B(x_{jmax} - x_{jmin})(f_i/f_{max}))$$

Where;
$x_{i+m,j}$ = offspring/children
$x_{i,j}$    = parents
N      = Gaussian random variable with mean and variance
B      = search step
$x_{jmax}$ = maximum parents
$x_{jmin}$ = minimum parents
$f_i$       = fitness 'i[th]'
$f_{max}$   = maximum fitness

f.   Fitness 2
−   Generation of new 20data of offspring from the mutation process.
−   Also known as offspring data
g.   Combination
−   This section consists of the combination process from the parent and offspring data.

− The matrix data will be doubled in size, from 20 data to 40 data, that is 20 data from parent and 20 data from offspring.

Parent + offspring

$[\ n_p\ X1_p\ X2_p\ X3_p\ P1_p\ P2_p\ P3_p\ P_{lossp}\ ]$

$[\ n_1\ X1_1\ X2_1\ X3_1\ P1_1\ P2_1\ P3_1\ P_{loss1}\ ]$

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$[\ n_{20}\ X1_{20}\ X2_{20}\ X3_{20}\ P1_{20}\ P2_{20}\ P3_{20}\ P_{loss20}\ ]$

$[\ n_o\ X1_o\ X2_o\ X3_o\ P1_o\ P2_o\ P3_o\ P_{losso}\ ]$

$[\ n_1\ X1_1\ X2_1\ X3_1\ P1_1\ P2_1\ P3_1\ P_{loss1}\ ]$

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$[\ n_{20}\ X1_{20}\ X2_{20}\ X3_{20}\ P1_{20}\ P2_{20}\ P3_{20}\ P_{loss20}\ ]$

− 20 populations of parents and a 20 population of offspring are combined together and forming the matrix 40x8 data.
h. Selection
− In this section, the population was sorted ascending order according to the fitness value.
i. Convergence test
− This part, determine either the maximum and minimum fitness fulfil the desired qualification or not. If the fitness does not meet the qualification, the process will automatically repeated again to the fitness 1 and continue until the qualification is fulfil.
− (Fitness max – fitness min <= ℰ): ℰ can be 0.00001, 0.0001, 0.001 or any value depend on the programmer.
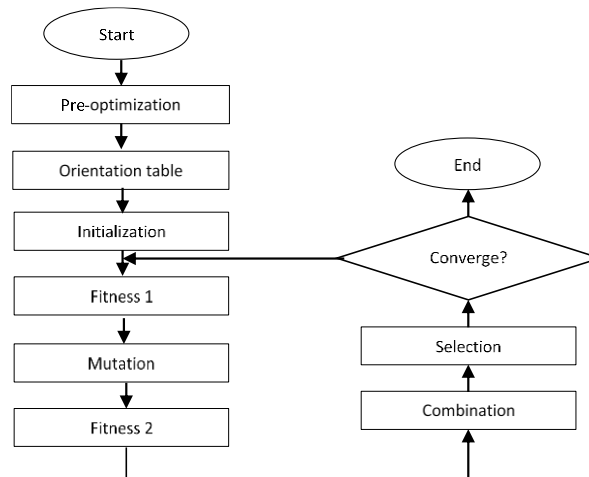


Figure 1. Supervised Evolutionary Programming

## 3. RESULTS AND DISCUSSION
### 3.1. Power loss before optimization

Table 1 shows the condition of power loss in the 69-bus system during the pre-optimization. Pre-optimization refer to the condition before the multi-DGs are appliance into the system, which refers to the unstable condition. From the table shows that the Plosses increases directly proportional to the increment of lambda, λ. As power demand increases, there will be a higher power losses due to the energy decreases in the equipment in the distribution system. The main factor of the power losses is due to the distance of distribution line. The higher the current passing through the distribution system, the higher the load demand,

thus result in higher line resistance cause the losses of I²R in the system. Figure 2 shows the graph of increment against power losses before optimization.

Table 1. Value of power loss before optimization

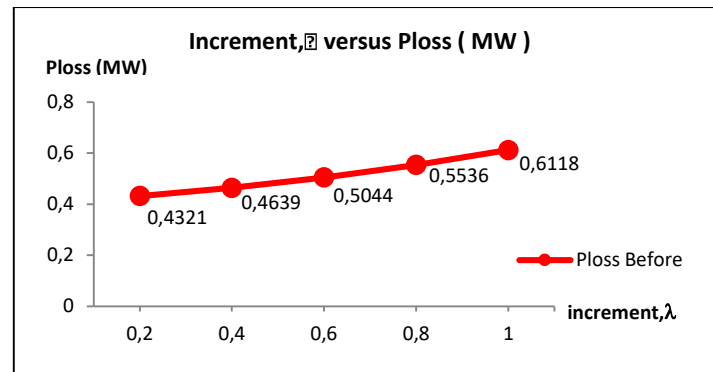| Increment,λ | Plosses (MW) |
|---|---|
| 0.2 | 0.4321 |
| 0.4 | 0.4639 |
| 0.6 | 0.5044 |
| 0.8 | 0.5536 |
| 1.0 | 0.6118 |



Figure 2. Graph of increment against power losses before optimization

## 3.2. Power loss after optimization

Table 2 shows the result after optimized location and sizing of multi-DGs and also the result of power loss. Based on the result obtained, the location is the same even the increment is increased, it is due to the value of DGs is fixed. The optimization of the location converged after 3 iterations. From the table also show that the value of the loss after optimization is decrease compared the value before optimization. Figure 3 shows the graph of increment against power loss after optimization.

Table 2. Table of power loss after optimization

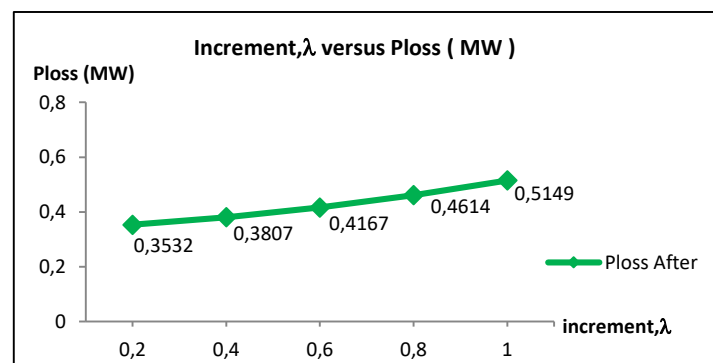| Increament,λ | Ploss after | X1 | X2 | X3 | P1 | P2 | P3 |
|---|---|---|---|---|---|---|---|
| 0.2 | 0.3532 | 47 | 48 | 65 | 0.1267 | 0.2534 | 0.3802 |
| 0.4 | 0.3807 | 47 | 48 | 65 | 0.1267 | 0.2534 | 0.3802 |
| 0.6 | 0.4167 | 47 | 48 | 65 | 0.1267 | 0.2534 | 0.3802 |
| 0.8 | 0.4614 | 47 | 48 | 65 | 0.1267 | 0.2534 | 0.3802 |
| 1.0 | 0.5149 | 47 | 48 | 65 | 0.1267 | 0.2534 | 0.3802 |



Figure 3. Graph of increment against power losses after optimization

### 3.3. Comparison of plosses before and after optimization

Based on Table 3 and Figure 4, the result shows that power loss had been optimized. The power losses before optimization or know as pre-optimization has been decreased after the optimization process.

Table 3. Comparison of losses before and after optimization

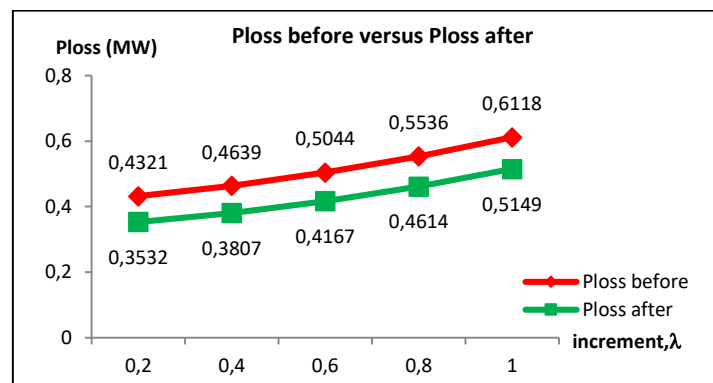| Increment,λ | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
|---|---|---|---|---|---|
| Ploss before | 0.4321 | 0.4639 | 0.5044 | 0.5536 | 0.6118 |
| Ploss after | 0.3532 | 0.3807 | 0.4167 | 0.4614 | 0.5149 |
| X1 | 47 | 47 | 47 | 47 | 47 |
| X2 | 48 | 48 | 48 | 48 | 48 |
| X3 | 65 | 65 | 65 | 65 | 65 |
| P1 | 0.1267 | 0.1267 | 0.1267 | 0.1267 | 0.1267 |
| P2 | 0.2534 | 0.2534 | 0.2534 | 0.2534 | 0.2534 |
| P3 | 0.3802 | 0.3802 | 0.3802 | 0.3802 | 0.3802 |



Figure 4. Ploss before versus Ploss after

### 4. CONCLUSION

As a conclusion, a supervised evolutionary programming technique able to solve the power system performance and optimize the location of the multi-DGs in order to minimize the power losses. The proposed method, proposing the orientation table in order to prevent the algorithm from collapsing in local minimum locations. The method able to enhance the performance of the distribution system by minimizing the total power loss in the system and optimize the best location of multi-DGs at the selected bus. The proposed method that is supervised evolutionary programming is better at evaluating the optimal DG location and power due to the active power range is already been set and fixed.

### REFERENCES

[1]     D. B. Prakash and C. Lakshminarayana, "Multiple DG Placements in Distribution System for Power Loss Reduction Using PSO Algorithm," *Procedia Technol.*, vol. 25, no. Raerest, pp. 785–792, 2016.
[2]     A. Khodabakhshian and M. H. Andishgar, "Simultaneous Placement and Sizing of DGs and Shunt Capacitors in Distribution Systems by Using IMDE Algorithm," *Int. J. Electr. Power Energy Syst.*, vol. 82, pp. 599–607, 2016.
[3]     M. A. Alotaibi and M. M. A. Salama, "An Efficient Probabilistic-Chronological Matching Modeling for DG Planning and Reliability Assessment in Power Distribution Systems," *Renew. Energy*, vol. 99, pp. 158–169, 2016.
[4]     B. Bakhshideh Zad, H. Hasanvand, J. Lobry, and F. Vallée, "Optimal Reactive Power Control of DGs for Voltage Regulation of MV Distribution Systems Using Sensitivity Analysis Method and PSO Algorithm," *Int. J. Electr. Power Energy Syst.*, vol. 68, pp. 52–60, 2015.

[5]   S. Gopiya Naik, D. K. Khatod, and M. P. Sharma, "Optimal Allocation of Combined DG and Capacitor for Real Power Loss Minimization in Distribution Networks," *Int. J. Electr. Power Energy Syst.*, vol. 53, pp. 967–973, 2013.

[6]   J. Angalaeswari. S, "Optimal Placement and Sizing of Real Power Supporting DG in Radial Distribution Networks," *Wiecon-Ece*, pp. 342–345, 2015.

[7]   A. El-Fergany, "Optimal Allocation of Multi-Type Distributed Generators Using Backtracking Search Optimization Algorithm," *Int. J. Electr. Power Energy Syst.*, vol. 64, pp. 1197–1205, 2015.

[8]   C. Yammani, S. Maheswarapu, and S. K. Matam, "A Multi-Objective Shuffled Bat Algorithm for Optimal Placement and Sizing of Multi Distributed Generations with Different Load Models," *Int. J. Electr. Power Energy Syst.*, vol. 79, pp. 120–131, 2016.

[9]   S. A. ChithraDevi, L. Lakshminarasimman, and R. Balamurugan, "Stud Krill Herd Algorithm for Multiple DG Placement and Sizing in a Radial Distribution System," *Eng. Sci. Technol. an Int. J.*, 2016.

[10]  S. Kansal, V. Kumar, and B. Tyagi, "Optimal Placement of Different Type of DG Sources in Distribution Networks," *Int. J. Electr. Power Energy Syst.*, vol. 53, no. 1, pp. 752–760, 2013.

[11]  R. Viral and D. K. Khatod, "An Analytical Approach for Sizing and Siting of DGs in Balanced Radial Distribution Networks for Loss Minimization," *Int. J. Electr. Power Energy Syst.*, vol. 67, pp. 191–201, 2015.

[12]  M. M. Othman, W. El-Khattam, Y. G. Hegazy, and A. Y. Abdelaziz, "Optimal Placement and Sizing of Voltage Controlled Distributed Generators in Unbalanced Distribution Networks using Supervised Firefly Algorithm," *Int. J. Electr. Power Energy Syst.*, vol. 82, pp. 105–113, 2016.

[13]  B. Mohanty and S. Tripathy, "A Teaching Learning Based Optimization Technique for Optimal Location and Size of DG in Distribution Network," *J. Electr. Syst. Inf. Technol.*, vol. 3, no. 1, pp. 33–44, 2016.

[14]  W. L. Theo, J. S. Lim, W. S. Ho, H. Hashim, and C. T. Lee, "Review of Distributed Generation (DG) System Planning and Optimisation Techniques: Comparison of Numerical and Mathematical Modelling Methods," *Renew. Sustain. Energy Rev.*, vol. 67, pp. 531–573, 2017.

[15]  N. Mohandas, R. Balamurugan, and L. Lakshminarasimman, "Optimal Location and Sizing of Real Power DG Units to Improve the Voltage Stability in the Distribution System using ABC Algorithm United with Chaos," *Int. J. Electr. Power Energy Syst.*, vol. 66, pp. 41–52, 2015.

[16]  A. Colmenar-Santos, C. Reino-Rio, D. Borge-Diez, and E. Collado-Fernández, "Distributed Generation: A Review of Factors that can Contribute Most to Achieve A Scenario of DG Units Embedded in the New Distribution Networks," *Renew. Sustain. Energy Rev.*, vol. 59, pp. 1130–1148, 2016.

[17]  B. Das, V. Mukherjee, and D. Das, "DG Placement in Radial Distribution Network by Symbiotic Organisms Search Algorithm for Real Power Loss Minimization," *Appl. Soft Comput. J.*, vol. 49, pp. 920–936, 2016.

[18]  M. M. Aman, G. B. Jasmon, A. H. A. Bakar, and H. Mokhlis, "A New Approach for Optimum DG Placement and Sizing Based on Voltage Stability Maximization and Minimization of Power Losses," *Energy Convers. Manag.*, vol. 70, pp. 202–210, 2013.

[19]  J. A. Martín García and A. J. Gil Mena, "Optimal Distributed Generation Location and Size using A Modified Teaching–Learning Based Optimization Algorithm," *Int. J. Electr. Power Energy Syst.*, vol. 50, pp. 65–75, 2013.

[20]  R. Hemmati, R.-A. Hooshmand, and N. Taheri, "Distribution Network Expansion Planning and DG Placement in the Presence of Uncertainties," *Int. J. Electr. Power Energy Syst.*, vol. 73, pp. 665–673, 2015.

[21]  M. H. Moradi, S. M. Reza Tousi, and M. Abedini, "Multi-Objective PFDE Algorithm for Solving the Optimal Siting and Sizing Problem of Multiple DG Sources," *Int. J. Electr. Power Energy Syst.*, vol. 56, pp. 117–126, 2014.

[22]  M. M. Aman, G. B. Jasmon, H. Mokhlis, and A. H. A. Bakar, "Optimal Placement and Sizing of A DG Based on A New Power Stability Index and Line Losses," *Int. J. Electr. Power Energy Syst.*, vol. 43, no. 1, pp. 1296–1304, 2012.

[23]  D. Q. Hung, N. Mithulananthan, and K. Y. Lee, "Optimal Placement of Dispatchable and Nondispatchable Renewable DG Units in Distribution Networks for Minimizing Energy Loss," *Int. J. Electr. Power Energy Syst.*, vol. 55, pp. 179–186, 2014.

[24]  S. A. Taher and M. H. Karimi, "Optimal Reconfiguration and DG Allocation in Balanced and Unbalanced Distribution Systems," *Ain Shams Eng. J.*, vol. 5, no. 3, pp. 735–749, 2014.

[25]  M. H. Lokman et al., "Multi-Verse Optimization Based Evolutionary Programming Technique for Power Scheduling in Loss Minimization Scheme," IAES Int. J. Artif. Intell., vol. 8, no. 3, pp. 292–298, 2019.

[26]  K. Lenin, "Integrated Algorithm for Decreasing Active Power Loss," IAES Int. J. Artif. Intell., vol. 7, no. 1, pp. 33–41, 2018.

[27]  T. Ananthapadmanabha and S. Rani D.N., "Optimal Allocation of Combined DG and Capacitor Units for Voltage Stability Enhancement," *Procedia Technol.*, vol. 21, pp. 216–223, 2015.

[28]  M. Tajdinian and F. Shabaninia, "A New DG Allocation Approach Based on Biogeography-Based Optimization with Considering Fuzzy Load Uncertainty," Proc. IEEE Int. Conf. Transm. Distrib. Constr. Live Line Maintenance, ESMO, vol. 4, no. 3, pp. 89–96, 2017.

[29]  W. Guan, Y. Tan, H. Zhang, and J. Song, "Distribution System Feeder Reconfiguration Considering Different Model of DG Sources," *Int. J. Electr. Power Energy Syst.*, vol. 68, pp. 210–221, 2015.