Determination of Optimal Site of a Distributed Generator for Power Loss Improvement based on Firefly Algorithm

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Abstract -**The distribution network is one of the most important parts of the energy system, because it is the final interface that leads to the most customers. Therefore, it is essential to maintain good quality energy with a good voltage profile provided by a minimum power loss. To ensure the latter, the introduction of Distributed Generation (DG) in the distribution network plays a key role. The location and size of DG are important because a bad selection has a negative impact on the system behavior. This paper proposes a Firefly algorithm (FA) to solve this problem by optimizing the location and size of DGs in radial distribution system. FA is a meta-heuristic algorithm which is inspired by the flashing behavior of fireflies. The main motive of firefly's flash is to behave as a signal for other fireflies to attract. In this paper, IEEE 30 -bus distribution test system is used to show the effectiveness of the FA. Comparison with genetic algorithm (GA) is also discussed to show its effectiveness.**

Keywords—Distributed Generation (DG), Distribution Systems, optimal DG allocation and Firefly Algorithm (FA)

I.INTRODUCTION

As the country starts developing, the need of energy also starts growing. This leads to burden in power generating plants and distributed network (DN) gets affected severely. To meet this demand environmental, and high cost are major hurdles for power transmission network expansion, which necessitates the need to explore the unused potential of the transmission system capacity.

In this modern era, the thirst of achieving more reliable and sustainable power leads to development of more advanced and improved DG equipment. This development has made a key factor for finding the optimal site and capacity in DN. On Optimising the Distributed Generation (DG) size and locating in Distributed Network (DN) can improves voltage and reduces network losses.

The "Distributed Generation" (DG) or Decentralized generation refers to the production of electricity near the consumption place. DG resources are obtained from natural resources such as wind, sunlight, tides, waves, geothermal heat and biomass. This can reduce power losses, improve reliability of the system, improve the power quality and provide voltage support.

In DN, the losses and voltage drop across the network are significant matters and the Distributed Generation (DG) location has a critical impact on the network operation. So, there is a clear need to optimise the DG size and location in the DN.

Due to high R/X ratio of radial DN matrix based transmission load flow methods such as Guass-Seidel, Newton-Raphson and etc. are not able to solve such systems. Thus distribution load flow (DLF) methods were developed to handle the properties of distribution systems[1],[2].

There have been many developed algorithms and solutions that can be used to investigate the allocation of DG in a DN. The differences among these algorithms are about the formulation of the problem, the proposed techniques and their assumptions.

To minimize the power losses, improve voltage stability and voltage profileAbdulwahab, Farrag, Bevan and Hepburn[3] used Genetic Algorithm and found that it is more efficient to find the optimal location than searching manually.Ghoiamreza, Roya and M.J. Azad[4]used a Particle Swarm Optimization algorithm in a 69-bus distribution network, where they reported that DG location and sizing problem can be evaluated more effectively than Genetic Algorithm (GA).

In this paper, Firefly Algorithm (FA) will be discussed for optimal al- location of DG in the radial DN to achieve our primary objective i.e. to reduce power losses.

The Firefly Algorithm (FA) is a metaheuristic, nature-inspired, optimization algorithm which is based on the social (flashing) behavior of fireflies, or lighting bugs, in the summer sky in the tropical temperature regions. It was developed by Dr. Xin-She Yang at Cambridge University in 2007 and it is based on the swarm behavior. In particular, although the firefly algorithm has many similarities with other algorithms which are based on the so-called swarm intelligence, such as the famous Particle Swarm Optimization (PSO), Artificial Bee Colony optimization (ABC) and Bacterial Foraging (BFA) algorithms. Furthermore, according to recent bibliography, the algorithm is very efficient and can outperform other conventional algorithms, such as genetic algorithms, for solving many optimization problems, a fact that has been justified in a recent research, where the statistical performance of the firefly algorithm was measured against other well-known optimization algorithms using various standard stochastic test functions. Its main advantage is the fact that it uses mainly real random numbers, and it is based on the global communication among the swarming particles (the fireflies), and as a result, it seems more effective in multi-objective optimization In this area, the most of studies have focused their research on the peak load level and so the uncertainty variations of loads have been considered However, in the time horizon of a day, a month or a year, the active and reactive load values may experience severe changes and the operator have to consider these variations. As a result of uncertainty associated with the variation of loads during the day, the operation and control of distribution networks are very complex and can be modeled as a nonlinear optimization problem According to the above discussion, in this work, the uncertainty in variation of loads is linearly changed from 50% to 150% of its nominal value in 1% steps. In this paper DGs are considered as an active power source. The best sizing and placement of multiple DGs unit in the distribution system to minimize the total loss are fond by firefly algorithm. This will also improve the voltage profile.

II. DISTRIBUTION SYSTEM ANALYSIS

A. *Modeling*

The distribution system is assumed to be operating under balanced condition and a single-phase model is used. Fig. 1 shows a simple model of a radial distribution system line. According to Fig. 1, the branch number is the number of receiving bus. In addition, Bus i or sending bus is the closer bus of line j to the slack bus or main substation and bus j or the receiving bus is the farther bus of line j to the slack bus. Line charging effects modeled as capacitive elements are negligibly small at the distribution level, and thus are not included in the distribution system line model [5], [6].

B. *Load Flow Equations*

The receiving end bus can be calculated using following equation [2].

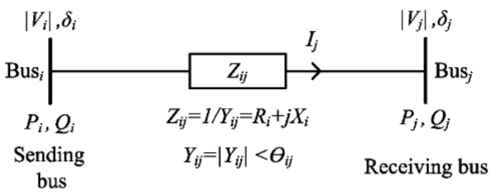


Fig. 1. A simple model of a distribution system line

$$V_j^2 = -\left[R_{ij}P_j + X_{ij}Q_j - \frac{V_i^2}{2}\right] + \sqrt{\left[R_{ij}P_j + X_{ij}Q_j - \frac{V_i^2}{2}\right]^2 - \left(R_{ij}^2 + X_{ij}^2\right)\left(P_j^2 + X_j^2\right)} \qquad (1)$$

Using value of receiving end bus voltage, the receiving bus angle can be calculated by equation given below.

$$\delta_j = \delta_i - \sin^{-1}\left(\frac{X_{ij}P_j - R_{ij}Q_j}{V_i V_j}\right) \qquad (2)$$

Since real and reactive powers of PQ bus are known, voltage and angle of PQ bus can be calculated using (1) and (2), respectively [5].

C. *Load Flow with DG*

In distribution system, any bus containing a generator with controllable bus voltage is a PV bus. Reactive power of PV bus is determined using the reactive power injection equation given below.

$$\delta_j = \delta_i - \sin^{-1}\left(\frac{X_{ij}P_j - R_{ij}Q_j}{V_i V_j}\right) \qquad (2)$$

In the above equation, K refers to the subscripts of all buses attached to bus j (including bus j) [5].

Since the values of reactive power of generators are limited in the range [Q_{min}, Q_{min}], calculation of reactive power for PV bus using equation (3) is not adequate.

D. *Calculation of Line Losses*

The line losses of line j connected to bus j can be calculated using following equations:

$$P_{Lossj} = R_{ij}\frac{\left(P_j^2 + Q_j^2\right)}{V_j^2} \qquad (4)$$

$$Q_{Lossj} = X_{ij}\frac{\left(P_j^2 + Q_j^2\right)}{V_j^2} \qquad (5)$$

E. *Constraints*

1) *Convergence Criteria*

For each bus, the following equations must be satisfied:

$$Q_{gi} - Q_{di} - V_i\sum_{j=1}^{N} V_j Y_{ij}\sin(\delta_i - \delta_j - \theta_{ij}) < \varepsilon \qquad (7)$$

Where, P_{gi} , P_{di} , N , and ε are the generated real power of probable DG in bus *i* , the nominal real power of load in bus *i* , the number of buses in distribution system, and maximum allowable absolute power mismatch, respectively. Q_{gi} and Q_{di} are the generated real power of probable DG in bus *i* and the nominal reactive power of load in bus*i* , respectively.

2) *DG Technical Constraints*

As DG capacity is essentially limited by the energy resource, real power generation of DG is limited between the maximum and the minimum level [6]. Reactive power generation of DG is also limited. These constraints must be considered in load flow and optimization problem.

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \qquad (8)$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max} \qquad (9)$$

3) *Power Transfer Limitation of Lines*

The maximum power transfer of lines in power system is limited because of thermal limitation of power lines.

$$S_{l(i,j)} \le S_{l(i,j)}^{max} \qquad (10)$$

F. Algorithm of Load Flow with DG

FIREFLY ALGO RITHM

The firefly algorithm has three particular idealized rules which are based on some of the major flashing characteristics of real fireflies. These are the following:

1) All fireflies are unisex, and they will move towards more attractive and brighter ones regardless their sex.

2) The degree of attractiveness of a firefly is proportional to its brightness which decreases as the distance from the other firefly increases due to the fact that the air absorbs light. If there is not a brighter or more attractive firefly than a particular one, it will then move randomly.

3) The brightness or light intensity of a firefly is determined by the value of the objective function of a given problem. For maximization problems, the light intensity is proportional to the value of the objective function

F. *Algorithm of Load Flow with DG*

The algorithm of load flow for radial distribution system with DG considering constraint is shown in Fig. 2

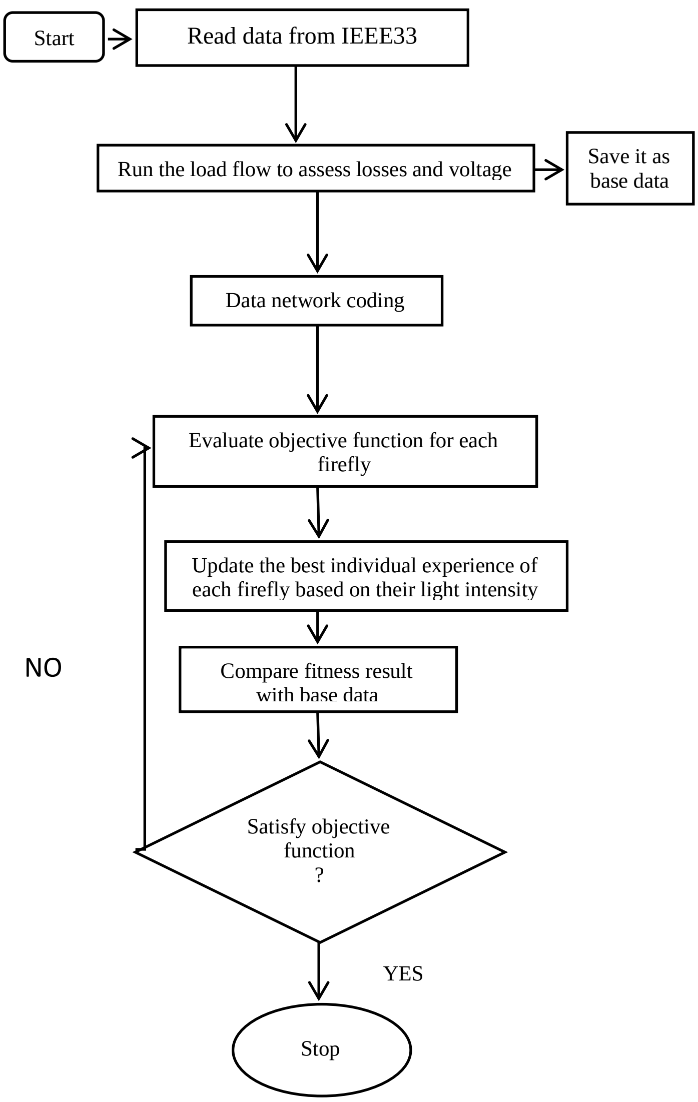


Figure 2: Flow chart of the FA method

For simplicity, the following three ideal rules are introduced in FA development [7]: 1) all fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex, 2) attractivenessvis proportional to their brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one, 3) the brightness of a firefly is affected by the landscape of the objective function. For maximization problem, the brightness can simply be proportional to the value of the objective or fitness function. The basic steps of the FA can be summarized as the pseudo code which is depicted in Fig.3 [7].

Firefly Algorithm………………………………………………..

Objective function $f(\mathbf{x})$, $\mathbf{x} = (x_1, \ldots, x_d)^T$

Generate initial population of fireflies $\mathbf{x}_i$ ($i=1, 2\ldots, n$)

Light intensity Ii at x_i *is determined by* $f(\mathbf{x}_i)$

Define light absorption coefficient γ

while ($t < MaxGeneration$)

for $i = 1$*: n all n fireflies*

for $j = 1$*: i all n fireflies*

if ($I_j > I_i$), *More firefly i towards j in d-dimension;* **end if**

Attractiveness varies with distance r via exp[$-\gamma r$]

Evaluate new solutions and update light intensity

end for j

end for i

Rank the fireflies and find the current best

end while

Post process results and visualization……………………………..

Fig. 3. Pseudo code of FA

The movement of a firefly *i* is attracted to another, more attractive (brighter) firefly *j* is determined by

$$x_i^{t+1} = x_i^t + \beta_0 \, e^{-\gamma r_{ij}^2} (x_j^t - x_i^t) + \alpha \varepsilon_i^t$$

where β_0 is the attractiveness at the distance r=0, and the second term is due to the attraction. The third term is randomization with α being the randomization parameter, and ε_i^t is a vector of random numbers drawn from a Gaussian distribution or uniform distribution at time *t*. If β_0=0, it becomes a simple random walk. Furthermore, the randomization ε_i^t can easily be extended to other distributions such as Lévy flights.

The Lévy flight essentially provides a random walk whose random step length is drawn from a Lévy distribution.

$$L(s, \lambda) = s^{-(1+\lambda)}, \quad (0 < \lambda \leq 2)$$

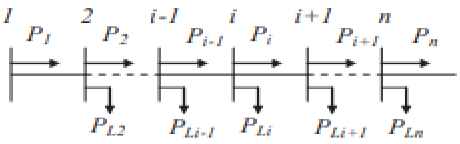
which has an infinite variance with an infinite mean. Here the steps essentially form a random walk process with a power-law step-length distribution with a heavy tail. Some of the new solutions should be generated by Lévy walk around the best solution obtained so far; this will often speed up the local search [7].

III. RESULTSANDANALYSIS

The calculation of the load flow of distribution system is different from that of transmission system because is radial in nature and has high R/X ratio. In the proposed method of load flow analysis the main aim is to reduce the data preparation and to assure computation for any size for distribution network. The proposed algorithm can know the topology of the grid, just by reading line and bus data. The voltage of each node is calculated by using a simple algebraic equation.

Although this method is based on the forward sweep, it calculates the power flow of simple and complex radial distribution networks.

DG size: 0.01 MW< PDG < 2 MW



Here we have taken IEEE-33 bus system line diagram of which is given below:

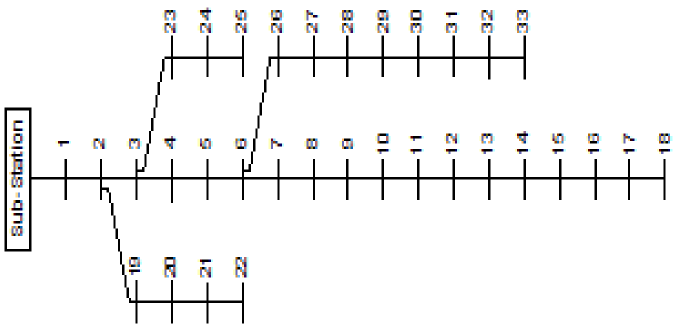


Fig.(4) IEEE-33 bus system line diagram

The comparison of the result is shown below and after placement of DG using FA algorithm:

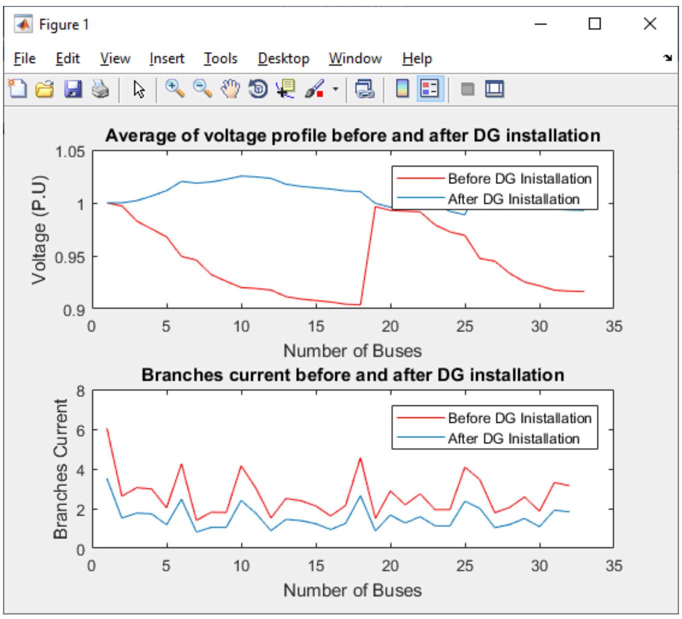


Figure 5:Voltage profile and losses before DG after DG

IV.CONCLUSION

The optimization method, based on the algorithm of the FA, was used to find the most appropriate network topology distribution IEEE33-bus with the objective to have the minimum power loss with an eligible voltage profile. The optimal obtained configuration meets the requirements; keep the radial structure of the network, and ensure the supply of all loads connected to the network. The results have proven the effectiveness of the algorithm.

REFERENCES

[1] M.A. Golkar, Electric Distribution System Operation and Design, K.N. Toosi University of Technology Press, 1999.
[2] A. Rost, B. Venkatesh and C. P. Diduch, “Distribution system with distributed generation load flow,” in IEEE Engineering Systems Conference, 2007.
[3] A. Determination of Optimal Site and Capacity of DG Systems in Distribution Network based on Genetic Algorithm. 2017;0–5.
[4] Johan Driesen and FaridKatiraei, “Design for distributed energyresources”,IEEE power and energy magazine, 2008.
[5] A. Rost, B. Venkatesh and C. P. Diduch, “Distribution system with distributed generation load flow,” in IEEE Engineering Systems Conference, 2007..
[6] H. Saadat, Power System Analysis, McGraw-Hill, 2001.
[7] X.-S. Yang, "Firefly algorithms for multimodal optimization,"Stochastic Algorithms: Foundation and Applications SAGA 2009, vol. 5792, pp. 169-178, 2009
[8] Srinivasa Rao R, Srinivasa Rao V. A generalized approach for determination of optimal location and performance analysis of FACTs devices.Int J Electr Power Energy Syst [Internet].2015;
[9] Zareiegovar G, Fesaghandis RR, Azad MJ, Modeling A. Optimal DG Location and Sizing in Distribution System to Minimize Losses , Improve Voltage Stability , and Voltage Profile.