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Optimal Sizing and Sitting of Distributed Genetation for Power System using Bacterial Foraging Algorithm

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Abstract: ***Distributed generation (DG) is the use of small generation sets connected to the grid or feeding power Islands based on technologies such as internal combustion engines, small and micro turbines, full cell, photo voltaic and wind plants. Driven by increasing environmental concerns and increasing amount of new generation technologies, it is expected that many new generation technologies, including renewable generation, will be connected to electrical power system in the near future, therefore, optimal sitting and sizing conditions shall be studied to improve overall power system operation. In this paper, improvement of voltage profile, improvement of voltage stability and less reduction is investigated. Bacterial foraging algorithm is directly utilized to study about nonlinear problems of sizing and sitting of distributed generation. Also, it is optimized using of Bacterial foraging algorithm and the simulation results is compared with genetic algorithm and particle swarm optimization. The 33-bus test system is employed in the study with dynamic load conditions. An Analysis on the potential impacts that DG might have on the stability and quality of the test system is studied. A simulation program, MATLAB, is used for this purpose, which executes dynamic calculations on the system***

Keywords: BFA algorithm; loss; indicator.

1. Introduction

Developments on distributed generation (DG) grows significantly, driven by environmental issues, e. g. as an effort to lower the carbon emission for the conventionally fossil – fueled power plants, as well as by economic issues, e. g. as an effort to substitute for transmission capacity and to respond to high electrical energy prices[1]. When DG is connected to the distribution network, the DG influences the technical aspects of the distribution grid [2]. The long as the distributed network with DG is not operated autonomously, i.e. isolated from the transmission network, the DG is a part of a large power pool and the power balance can be kept by the centralize machines transient stability may be neglected. However, when the penetration of DG increases, its impact is no longer restricted to the distribution network but starts to influence the whole system [3], including the transmission system transient stability. In this paper, the transient stability behavior of a distribution network with DG is investigated network. Hence, sizing and sitting of distributed generation for power system is used to reduce the losses of the power system network [4]. With the right usage and placement of DG in the distribution grid, we can achieve the best economic deal and stability for power consumption in the distribution grid. Several problems regarding power system stability, power quality and control may surface as increasing distribution generation is being integrated into the power system network. Therefore, In this paper, one fitness function is investigated using of bacterial foraging algorithm and its result is compared with genetic algorithm and particle swarm optimization.

2. Dispersed Generation Sizing and Sitting

To optimize dispersed generation sitting and sizing distribution network is devised to two branches according to following:

I. Suitable sitting about distributed generations
II. Suitable sizing about distributed generations

To optimize a nonlinear function, bacterial foraging algorithm is proposed as an intelligence method to achieve desired voltage profile and desired voltage stability and loss reduction. Therefore, the power system dynamic simulation package is used to achieve the dynamic behavior of the load variation, which alternately executes dynamic calculations. The objective function is defined as:

$$f = \min\left(f_1 + 0.3 \times f_2 + 0.6 \times f_3 + \sum_{i=1:N_{DG}} [\max(V_{ni} - 1.05, 0) + \max(0.95 - V_{ni}, 0)]\right) \quad (1)$$

According to equation (1), V_{ni} refers to ni-th bus where f_1, f_2 and f_3, respectively are network losses, voltage profile and network voltage stability.

2.1 Reduction Network Losses

Network losses, f_1 is presented by the following equation:

$$f_1 = \sum_{i=1}^{n_b} r_i \frac{P_i^2 + Q_i^2}{V_i^2} \quad (2)$$

According to equation (2), P_i and Q_i respectively are active power and reactive power that exits from i-th bus and V_i is the resistance of upper branch where it connects to i-th bus and V_i is the voltage of i-th bus.

2.2 Voltage Profile Improvement

The voltage profile can be written as follow:

$$f_2 = \sum_{i=1}^{n_b} (V_i - 1)^2 \quad (3)$$

2.3 Voltage Stability Indicator Improvement

By using dispersed generation sources in distributed network, stability indicator will change. This indicator defines as equation (4) [4].

$$SI = |V_i|^4 - 4[P_i r_i + Q_i x_i]|V_i|^2 - 4[P_i r_i + Q_i x_i]^2 \quad (4)$$

In equation (4), V_j is the voltage of upper bus. To increase the voltage stability indicator, f_3 defines as equation (5):

$$f_3 = \frac{1}{\min(SI)} \quad (5)$$

3. Bacterial Foraging Algorithm

In Foraging theory is based on the chemotactic behavior of E.coli bacteria, the ones that are living in intestines. It can be modeled in a optimization process. The bacterial foraging system consists of four principal mechanisms, namely chemotaxis, swarming, reproduction, and elimination dispersal. It is described each of these processes as follow.

A. Chemotaxis

This process simulates the movement of an E.coli cell through swimming and tumbling via flagella. Biologically, an E.coli bacterium can move in two different ways. It can swim for a period of time in the same direction, or it may tumble and alternate between these two modes of operation for the entire lifetime. Basically, the bacterium is trying to swim from places with low concentration of nutrients to places with high concentrations. An opposite type of behavior is used when it encounters noxious substances.

B. Swarming

A group of E.coli cells arrange themselves in a traveling ring by moving up the nutrient gradient when placed amidst a semisolid matrix with a single nutrient chemo effecter. The cells, when simulated by a high level of succinate, release an attraction aspertate, which helps them to aggregate into groups and thus move as concentric patterns of swarms with high bacterial density. The cell-to-cell signaling in E.coli swarm may be represented by the following function:

$$J_{cc}(\theta^i(j,k,l),\theta(j,k,l)) = \sum_{i=1}^{s} J_{cc}^i(\theta^i,\theta)$$
$$= \sum_{i=1}^{s}\left[-d_{attract}\exp\left(-\omega_{attract}\sum_{m=1}^{p}(\theta_m^i-\theta_m^i)^2\right)\right] \quad (6)$$
$$+\sum_{i=1}^{s}\left[-d_{repellant}\exp\left(-\omega_{repellant}\sum_{m=1}^{p}(\theta_m^i-\theta_m^i)^2\right)\right]$$

Where $J_{cc}(\theta, P(j,k,l))$ is the objective function value to be added to the actual objective function, S is the total number of bacteria, P is the number of Variables to be optimized that are present in each bacterium, and $\theta = [\theta_1, \theta_2, ..., \theta_p]^T$ is a point in the P-dimensional search domain.

$d_{arreactant}$, $w_{atractant}$, $h_{repellant}$, $w_{repellant}$ are different coefficients that should be chosen properly.

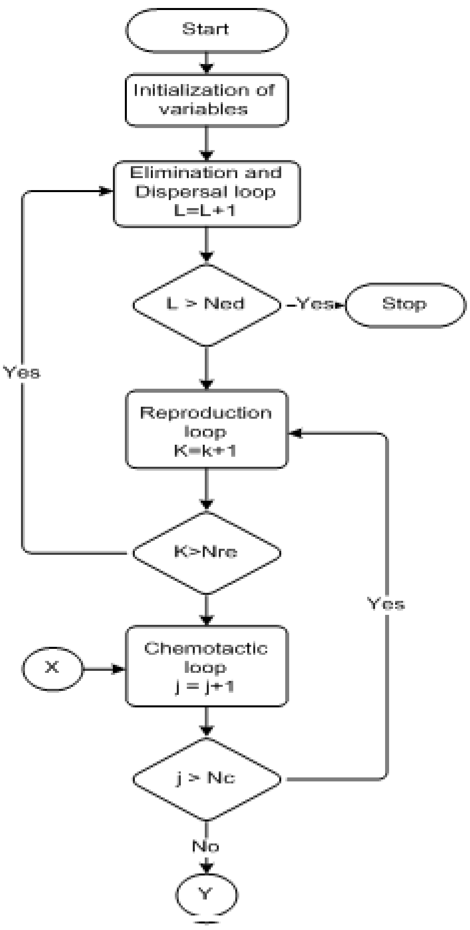
$$J_{cc}(\theta, P(j,k,l)) = \sum_{i=1}^{s} J_{cc}(\theta, \theta^i(j,k,l))$$
$$= \sum_{i=1}^{s}[-d_{attractant}\exp(-\omega_{attractant}\sum_{m=1}^{p}(\theta_m-\theta_m^i)^2)] \quad (6)$$
$$+\sum_{i=1}^{s} h_{repellant}\exp(-\omega_{repellant}\sum_{m=1}^{p}(\theta_m-\theta_m^i)^2)]$$

C. Reproduction

The least healthy bacteria eventually die while each of the healthier bacteria (those yielding lower value of the objective function) asexually split into two bacteria, which are then placed in the same location. This keeps the swarm size constant.

D. Elimination and Dispersal

Gradual or sudden changes in the local environment where a bacterium population lives may occur due to various reasons: e.g., a significant local rise of temperature may kill a group of bacteria that are in a region with a high concentration of nutrient gradients. Events can take place in such a fashion that all the bacteria in a region are killed or dispersed into a new region. The details and block diagram of the algorithm is given in fig 1. [5].



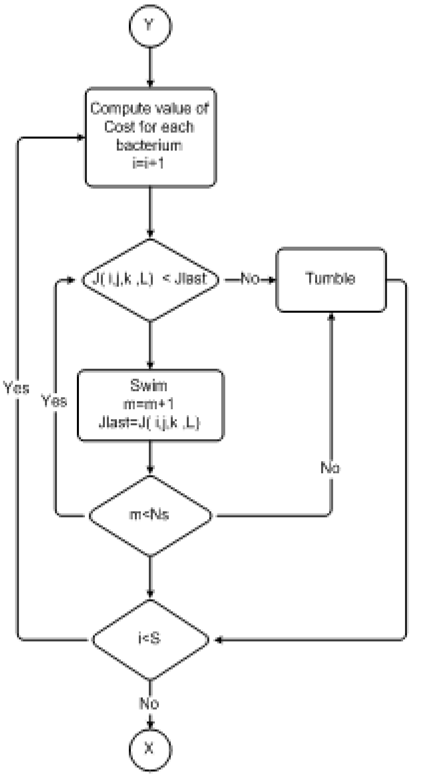


Figure 1: Flowchart of the bacterial foraging algorithm

Fig. 2 presents a configuration of 33-bus test system which is employed in this paper. Hence, Three kinds of load is considered (e.g., commercial, residential and industrial) for the 33-bus test system.

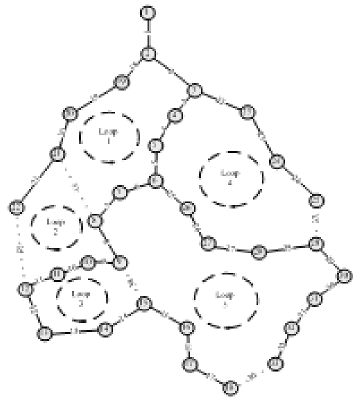


Figure 2: Sample configuration for studying 33-bus test system [6]

Ratio of any kind of loads is listed as table 3. [1], [5].

4. Simulation Results

Table 1: Ratio of different kind of loads

Bus number	*commercial*	*residential*	*industrial*	*Bus number*	*commercial*	*residential*	*industrial*
2	0.2	0.5	0.3	**18**	0.4	0.5	0.1
3	0.05	0.3	0.2	**19**	0.5	0.2	0.3
4	0.05	0.2	0.3	**20**	0.7	0.3	0
5	0.06	0.1	0.3	**21**	0.5	0.3	0.2
6	0.04	0.4	0.2	**22**	0.3	0	0.7
7	0.06	0	0.4	**23**	0.5	0.4	0.1
8	0.3	0.3	0.4	**24**	0.4	0.5	0.1
9	0.4	0.6	0	**25**	0.6	0.4	0
10	0.3	0	0.7	**26**	0.7	0.3	0
11	0.2	0.2	0.2	**27**	0.1	0	0.9
12	0.5	0.5	0	**28**	0.6	0.3	0.1
13	0.6	0.4	0	**29**	0.4	0.1	0.5
14	0.4	0.4	0.2	**30**	0.7	0.2	0.1
15	0.5	0.1	0.4	**31**	0.4	0.4	0.2
16	0.2	0.7	0.1	**32**	0.2	0.1	0.7
17	0.3	0.3	0.4	**33**	0.3	0.7	0

In this section, Three kinds of load is considered (e.g., commercial, residential and industrial) for the 33-bus test system according to Fig.3.

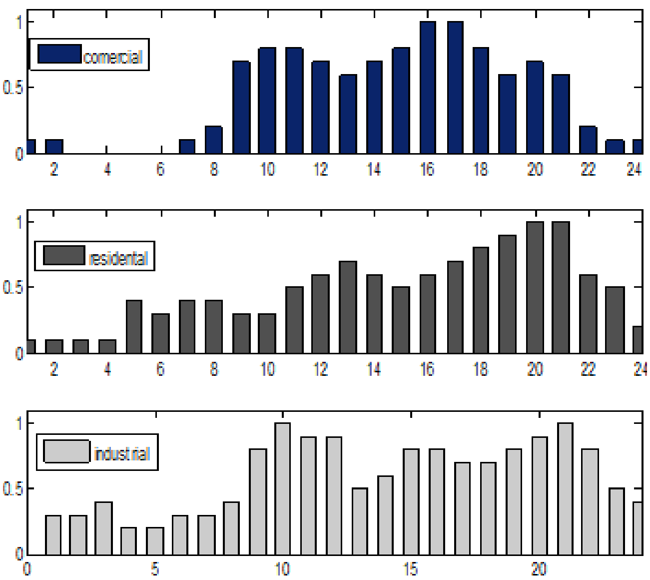


Figure 3: the voltage profile during a day for commercial, residential and industrial loads

Figure 4, presents simulation results in mentioned system. As shown Figure 4, the bacterial foraging algorithm shows better Convergence behavior as compared to the GA and PSO algorithm. Fig 4 exhibits fitness function value versus fitness function evaluation number.

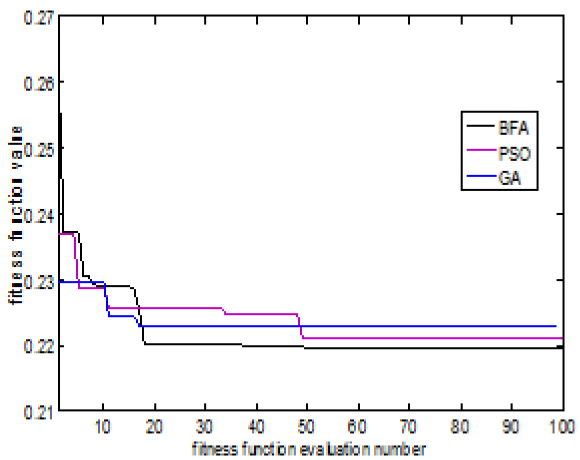


Figure 4: comparison between BFA, PSO and GA toward convergence for DGSS problem

5. Conclusion

In this paper, the bacterial foraging algorithm was used in the sizing and sitting of dispersed generation. Mentioned Algorithm on the system is also studied and its result was compared with GA and PSO algorithm moreover, the dynamic load was considered on 33-bus test system with transient loads during a day. To optimize dispersed generation sizing and sitting several factors was investigated (e.g.; losses, voltage profile, voltage stability indicator) they were replaced in fitness function. Hence, bacterial foraging algorithm used to optimize mentioned factors. Finally, the simulation results confirm its proper performance.

Table 2: Mention to initialized parameters of BFA algorithm.

Total number of bacteria in the population	s
Swimming length	N_s
The number of reproduction step	N_{er}
The number of elimination – dispersal events	N_{ed}
Elimination – dispersal probability	P_{ed}
The size of the step taken by the tumble	C_i

Table 3, shows proper location and capacity for DG, which extracts from BFA on studying system for static and dynamic loads.

Table 3: DGSS Results

Kind of loads	Location of DG	Capacity of DG(KW)	Sum of f_1	Sum of f_2	Sum of f_3	Sum of fitness function During a day
Static load	[18 16]	[242 248]	3.52	1.83	31.8	15.76
dynamic load	[17 33]	[250 250]	3.63	1.71	32.84	16.16

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