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# EFFECTIVE METHOD FOR OPTIMAL ALLOCATION OF DISTRIBUTED GENERATION UNITS IN RADIAL DISTRIBUTION SYSTEMS BY GENETIC ALGORITHM AND IMPERIALIST COMPETITIVE ALGORITHM

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**Abstract-** This paper proposes Genetic Algorithm (GA) and Imperialism Competitive Algorithm (ICA) for solving optimal distributed generation (DG) location and capacity. The objective is to minimize network power loss and improve the voltage stability index within the frame-work of system operation and security constraints in radial distribution systems. A detailed performance analysis is carried out on 33 bus system to demonstrate the effectiveness of the proposed methodology. Two different objective functions are considered in this study: (1) minimization of active power loss (2) maximization of improve the voltage stability index. The goal is to optimize each objective function. The site and size of DG units are assumed as design variables. The results are discussed and compared with those of traditional distribution planning and also with GA and ICA.

**Keywords:** Distributed Generation, Distribution Network Planning, Genetic Algorithm (GA), Imperialism Competitive Algorithm (ICA), Losses, Voltage Stability Index.

## I. INTRODUCTION

Distribution systems are usually radial in nature for operational simplicity. The Radial Distribution Systems (RDS) are fed at only one point, which is the substation. The substation receives power from the centralized generating stations through interconnected transmission network. The end users of electricity receive electrical power from the substation through RDS, which is a passive network. Hence, the power flow in the RDS is unidirectional. The high $R/X$ ratio of the distribution lines results in large voltage drops, low voltage stability and power losses. Under critical loading conditions in certain industrial areas, RDS experiences sudden voltage collapse due to low value of voltage stability index at most of its nodes [1-2]. Main reasons for the increasingly widespread usage of distributed generation can be summed up as follows [3]:

Some technology have been perfected and are widely practiced (gas turbines, internal combustion engines), others are finding wider applications in recent years (wind, solar energy) and some particularly promising technologies are currently being experimented or even launched (fuel cell, solar panels integrated into buildings). The DG units are closer to customers so that Transmission and Distribution (T&D) costs are avoided or reduced. The CHP (Combined Heat and Power) groups do not require large and expensive heat networks.

In order to achieve the aforementioned benefits, DG size has to be optimized. Researchers have developed many interesting algorithms and solutions. The differences are about the problem which is formulated, methodology and assumptions being made. Some of the methods are mentioned in [3] as analytical approaches [4] numerical programming, heuristic [5-6]. All methods own their advantages and disadvantages which rely on data and system under consideration. The allocation problem formulation of distributed generation is nonlinear, stochastic or evens a fuzzy function as either an objective function or constraints.

Generally, in all formulations the objective function is to minimize the real power losses and improve voltage; while abiding into all physical constraints equations in terms of voltage and power. The variable limits in the optimization procedure must also be obeyed. In distribution network planning, the planners usually focus on the voltage profile, power loss, and operation cost while satisfying different constraints such as safe operation and adequate service. Growing the load demand and competitive environment put emphasize both on cost and reliability of distribution networks.

Cost is typically expressed as per KWh of supplied load. A way to assess the reliability is calculating the ratio of time interval in which the electric energy is available to the whole time. Traditional planning has been implemented by reconfiguration and reinforcement of network, load switching, and capacitor installation.

Nowadays, a great attention has been paid to the presence of distributed generation in distribution system planning. DG is generally defined as power generation through the relatively small units (from a few KWh up to 10 MW).

The problem of optimal DG location and sizing is divided into two sub problems, where the optimal location for DG placement is the first and how to select the most suitable size is the second. Many researches proposed different methods such as analytic procedures as well as deterministic and heuristic methods to solve the problem. Keane and Malley [7] solved for the optimal DG sizing in the Irish system by using a constrained Linear Programming (LP) approach. The objective of their proposed method was to maximize the DG generation.

The nonlinear constraints were liberalized with the goal of utilizing them in the LP method. A DG unit was installed at all the system buses and the candidate buses were ranked according to their optimal objective function values. Kashem [8] developed an analytical approach to determine the optimal DG sizing based on power loss sensitivity analysis. Their approach was based on minimizing the distribution system power losses. The proposed method was tested using a practical distribution system in Tasmania, Australia.

Minimizing the system losses and total cost of DG, (Gandomkar et al., 2005; Lee and Park, 2009; Hamedani et al., 2009), improving the reliability indices and voltage profile (Wang and Nehrir, 2008; Zhu et al., 2006; Kim et al., 2008; Niknam et al., 2003), are some of the goals considered. This paper is organized as follow: A proposition is done for the problem formulation, the test power system and the optimization algorithm, after which the study discusses the simulation results from technical and economical points of view. Finally, the research is concluded.

## II. PROPOSED METHODOLOGY

The real power loss in a system is given as:

$$f_1 = \min\{P_{Loss}(P_{d1}, P_{d2}, ..., P_{dDG})\} \tag{1}$$

where $P_{di}$ stands for the rating capacity of distributed generation fixing in the $i$ bus; $P_{Loss}$ is the system network loss in relation to dynamo electric location and capacity. Figure 1 shows a branch of radial system. In radial distribution system each receiving node is fed by only one sending node, from Figure 1.

$$I_i = \frac{V_{mi} - V_{ni}}{R_{ni} + X_{ni}} \tag{2}$$

$$P_{ni}(ni) - Q_{ni}(ni) = V^*_{ni} I_{ni} \tag{3}$$

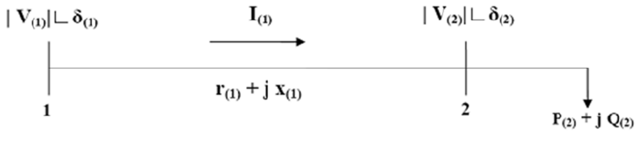

Figure 1. Representative Branch of a radial distribution system

When distributed generation is connected to distribution network, the index of voltage stability for distribution network will be changed. This index, which can be evaluated at all nodes in radial distribution systems, was presented in [5]. The Equation (3) represents the voltage stability index. Using Equation (4):

$$SI(n_2) = |V_{mi}|^4 .4[P_{ni}(ni)R_{ni} + Q_{ni}(ni)X_{ni}].|V_{mi}|^2 - \\ -4[P_{ni}(ni)R_{ni}.Q_{ni}(ni)X_{ni}]^2 \tag{4}$$

The Objective function for improving voltage stability index is:

$$f_2 = \left(\frac{1}{SI(ni)}\right) \quad , \quad i = 2, 3, ..., n_n \tag{5}$$

For stable operation of the radial distribution systems, $SI$ $(ni)$ > 0 for $i$ = 2, 3, ..., $n_n$, so that; there exists a feasible solution and feasible solution. It is very important to identify weak buses for nodes with minimum voltage stability index that are prone to voltage instability. Investigating the voltage stability index behavior demonstrate that the buses which experiencing large voltage drops are weak and within the context of remedial actions. So, it makes sense to act on controls that will improve the voltage magnitudes at weak buses. The constraints are as the followings:

$$P_{gi} - P_{di} - V_i \sum_{j=1}^{N} V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) = 0 \tag{6}$$

$$Q_{gi} - Q_{di} - V_i \sum_{j=1}^{N} V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) = 0 \tag{7}$$

$$V_i^{\min} < V_i < V_i^{\max} \quad , \quad i = 0, 1, ..., N_n \tag{8}$$

A DG capacity is inherently limited by the energy resource at any given location it is necessary to on strain capacity between maximum and minimum levels.

$$P_{gi}^{\min} < P_{gi} < P_{gi}^{\max} \tag{9}$$

$$Q_{gi}^{\min} < Q_{gi} < Q_{gi}^{\max} \tag{10}$$

Final thermal limit of distribution lines of the network must not be exceeded, shown in Equation (11).

$$|S_i| \le |S_i^{\max}| \quad , \quad i = 1, 2, ..., N_b \tag{11}$$

## III. SOLUTION METHODOLOGY

Following steps are involved in optimal sitting and sizing of DG in distribution system:

- Step 1: set the time counter $t = 0$ and generation randomly n chromosomes. $X_j(0), j = [1, \ldots, n]$, where $X_j(0) = [X_{j,1}(0), X_{j,2}(0), \ldots, X_{j,m}(0)]$, where $X_{j,k}(0)$ is generated in search space $[X_k^{\min}, X_k^{\max}]$ randomly.
- Step 2: evaluate each chromosome in the initial population using the objective function, $J$. The search for the best value of the objective function is $J_{best}$. Set the chromosome associated with $J_{best}$ as the global best.
- Step 3: update the time counter $t = t + 1$.

- Step 4: create a new population by repeating the following steps until the new population is complete:

- Selection: select two parent chromosomes from a population according to their fitness
- Crossover: with a crossover probability, cross over the parents to form a new children.
- Mutation: with a mutation probability method mutate new children at each chromosome.
- Acceptance: place new children in a new population

Step 5: use new generated population for a further run of algorithm.

- Step 6: if one of the stopping criteria is satisfied then stop, else go to step 2.

## IV. THE FITNESS FUNCTION

The limit conditions of upper and lower limit of distributed generation capacity are automatically satisfied in the phase of coding. Other limit conditions are plus to objective functions by penalty function. The improved formula of the objective function is in Equation (12).

$$
\begin{aligned}
& f=\min\{[f_1+k_1 f_2+ \\
& +\beta_1 \sum_{i\in N_{DG}} [\max(V_i-V_{i,\max},0)+\max(V_{i,\min}-V_i,0)]+ \qquad (12) \\
& +\beta_2 \sum_{j\in N_{DG}} [\max(|S_j|-|S_{j,\max}|,0)]\}
\end{aligned}
$$

where $\beta_1$, $\beta_2$ and $k_1$ are the penalty coefficients, $N_{DG}$ is the branch number and $k_1$ rate is the distributed generation number.

## V. APPLICATION STUDY AND NUMERICAL RESULTS

The proposed method for optimal multi-distributed generation has been implemented in the Matlab and tested for several power systems. In this section, the test results for Distribution system in [10] is presented and discussed. The studied distribution network is a radial system with the total load of 2.45 MW, 1.98 MVAR, 69 bus and 68 branches as it has been shown in Fig. 2. The real power loss in the system without DG is 1.556 KW when calculated using the load flow method is based on that reported in [11, 14]. The optimization is performed using Genetic Algorithm and Imperialism Competitive Algorithm software package was written for simulation of load shedding in radial distribution systems with and without Distributed generations. The parameters used in GA algorithm are: Number of iterations is 33; Population size is 100; Cross over probability is 0.8; and Mutation probability is 0.01. Also, the parameters used in ICA algorithm are: Number of Decade is 33; Population size is 100; Number of Empire 10; Revolution rate is 0.1.

The Tables 1 and 2 show the methods which are compared, location (bus number), DG size, and real power losses in Figure 4 shows which are basic columns. The power loss calculation of ICA is less than the results of GA. After installing DG, the voltage level for that bus is improved. Furthermore, the voltage levels at all nodes for RDS have improved. Convergence values for GA and ICA fitness functions are illustrated in Figure 3.

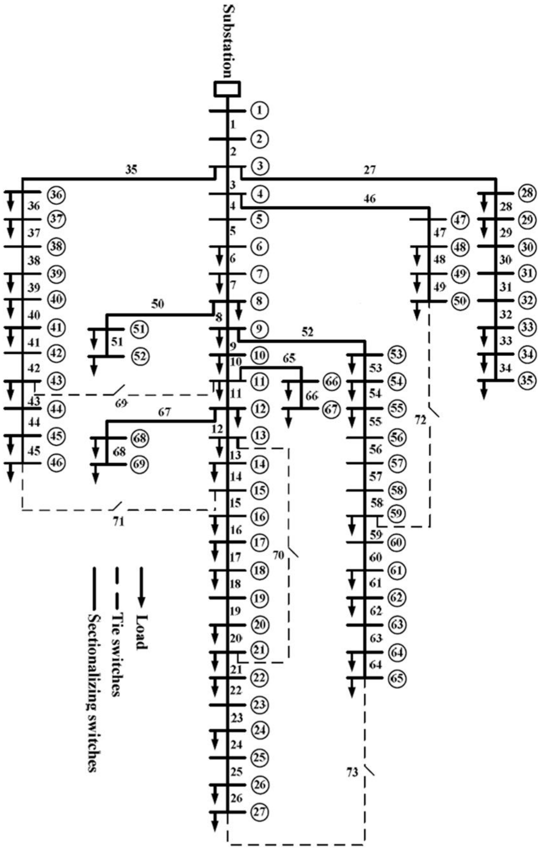

Figure 2. Single line diagram of a 69-bus distribution

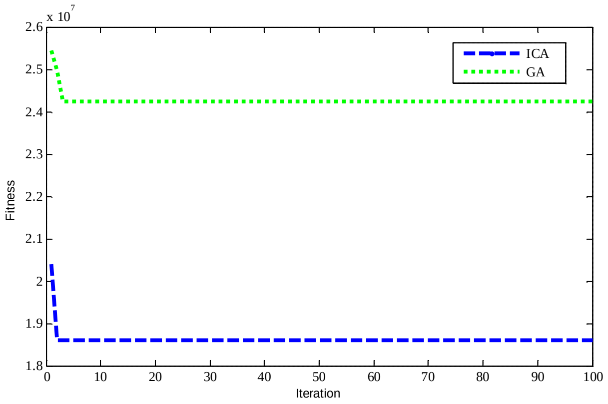

Figure 3. Convergence values for GA and ICA fitness functions

Table 1. Optimal place and size of the DG in 69-bus systems sing Imperialism Competitive Algorithm (ICA)

| Bus location | Capacity [MW] |
|---|---|
| 7 | 0.69 |
| 11 | 1.2 |
| 41 | 0.2 |
| 44 | 0.8 |
| 56 | 0.3 |
| 61 | 0.48 |

Table 2. Optimal place and size of the DG in 69-bus systems using Genetic Algorithm (GA)

| Bus location | Capacity [MW] |
|---|---|
| 3 | 0.47 |
| 17 | 1.035 |
| 26 | 1.52 |
| 33 | 0.345 |
| 49 | 0.5 |
| 64 | 1.5 |

The voltage profile for ICA and GA method is given in Figures 5 and 6. It can be seen that the voltage profile achieved by GA and ICA optimization algorithms are almost the same while having better improvement in compare with no DG state. The real power loss are 895.49 KW and 495.671 KW, which is approximately 5.654% and 5.433% in compare with No DG state design for GA and ICA, respectively.

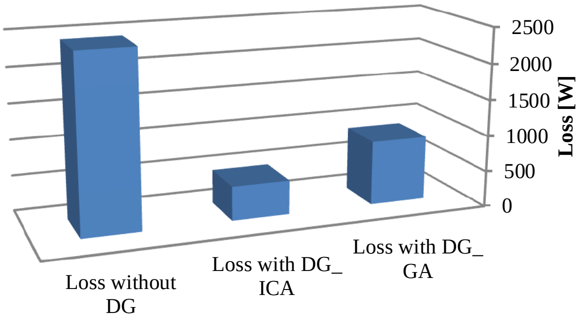

Figure 4. Bar losses profile with & without DG in 69-bus system

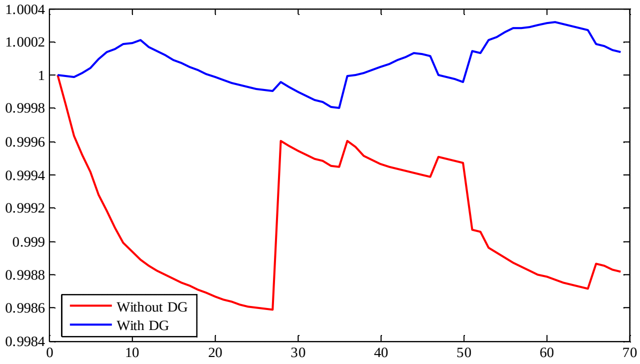

Figure 5. Voltage profile with and without DGs in 69-bus system using Genetic Algorithm (GA)

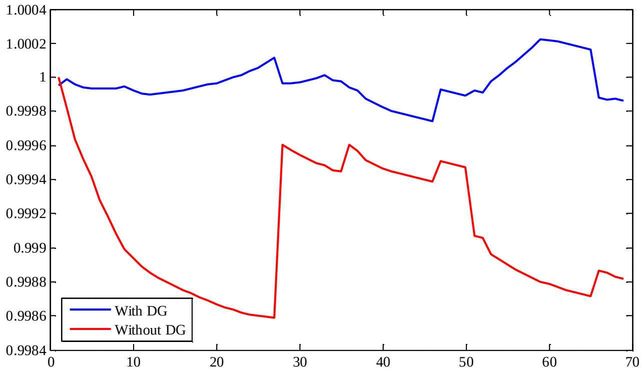

Figure 6. Voltage profile with and without DGs in 69-bus system using Imperialism Competitive Algorithm (ICA)

## VI. CONCLUSIONS

This paper is organized as follow: A proposition is done for the problem formulation, the test power system and the optimization algorithm, after which the study discusses the simulation results from technical and economical points of view. When installation and operation of distributed generation supplies are implemented based on optimization procedures, it can provide significant technical and economic advantages for the distribution companies. Regarding the various parameters which are effective in optimally locating the DG units, solving this problem has always been concerned with special complexity. In this paper, ICA and GA is proposed for optimal multi-distributed generation location and size. Test results indicate that the ICA algorithm is efficiently finding the optimal multi-distributed generation; compared to GA.

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