A LIFE CYCLE MODEL FOR OPTIMAL DG PLACEMENT ON DISTRIBUTION NETWORKS TO REDUCE ACTIVE LOSSES AND INVESTMENT COSTS

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ABSTRACT

This paper presents a new method named "Life cycle model" for optimal placement of Distributed Generators in a distribution network. The impact of DG at the distribution level is investigated with an emphasis on active power losses and allocation for minimizing the cost of losses and capacity investment costs simultaneously. An application of the proposed method for a distribution network is presented.

I. INTRODUCTION

With the introduction of restructuring concepts to traditional power systems, a great deal of attention is given to utilization of distributed generation. The definitions for distributed generation (DG) used in the literature are not the same. in [1] DG is defined as all small generators, typically ranging from 15 to 10000 KW, scattered throughout a power system, to provide the electric power needed by customers. In most power systems, a large portion of electricity demand is supplied by large-scale generators. This is because of economic advantages of these units over small ones. However, in the last decade, technological innovations and a changing economic and regulatory environment have resulted in a renewed interest for DG units [2]. A study by the Electric Power Research Institute (EPRI) indicates that by 2010, 25% of the new generation will be distributed. A study by the Natural Gas foundation concluded that this figure could be as high as 30% [3]. As mentioned in [4] there are five major factors behind this trend: electricity market liberalization, development in DG technology, constraints on the construction of new transmission lines, Reliability enhancement [5-6] and concerns about climate changes.

In addition to those indicated before, there are other important benefits in using DG units, which are as follows:

- Loss reduction of distribution networks
- Voltage profile improvement[7]
- Relieving T&D congestion
- Deferral of investments for upgrading of facilities
- Improving power quality
- Reduction of emission pollutants
- Voltage stability improvement [8]

In liberalized electricity markets, there is an incentive for distribution companies (DISCOs) to reduce the loss of distribution systems. Because DISCOs are paid a fix percent of loads as their losses so if they reduce losses their profit will increase otherwise the DISCOs benefits will decrease [9].The rest of this paper is structured as follows: in section II, problem formulation is introduced and discussed. A brief introduction to genetic algorithm an Hill Climbing Algorithm is brought in section III and IV. The proposed algorithm and simulation results are in section V, VI respectively.

II. PROBLEM FORMULATION

The problem is finding the best combination of some DG units among available categories and placing them on suitable buses in order to minimize the cost of losses and installed units. Injected power of DG units can change load flow patterns so if distributed generators are strategically placed in the power system, it can have a great effect on active system losses. Connection of a DG unit to a bus is modeled as a negative PQ load with a unity power factor. Obviously, the magnitude of this load is equal to capacity of DG unit. The following assumptions are employed in this formulation:

The cost of losses per MW ($Loss_{cost}$)

Total number of DG categories is given (N_T)

Total number of DG units in each category is given (N_{C_i})

Cost of DG units in each category is given ($Cost_{C_i}$)

Cost function has two components: the first one is the cost of active power losses in grid that can be calculated using (1).

$$\text{Cost of Losses} = Loss_{cost} \times \sum_{\ell \in L} \left(P_{i \to j}^{\ell} + P_{j \to i}^{\ell} \right) \quad (1)$$

Where,

$Loss_{cost}$: The cost of Active power losses in $\frac{\$}{\text{KW}}$,

L : The collection of all lines of the system

$P_{i \to j}^{\ell}$: The active flow injected to line ℓ from bus i to j,

$P_{j \to i}^{\ell}$: The active flow injected to line ℓ from bus j to i,

Cost of installed DG units

$$= \sum_{c_i \in C} \sum_{i=1}^{N_{C_i}} U_i^{C_i} \times Cost_{C_i} \quad (2)$$

Where,

c_i : The i th category of DG units,

C: All categories of DG units,

$U_i^{C_i}$: A binary variable representative of whether i th DG of Category c_i is installed ($U_i^{C_i} = 1$) or not ($U_i^{C_i} = 0$)

Objective function is

F= Cost of losses + Cost of installed DG units

Constraints:

Power flow equations

$$P_i = V_i \sum_{j=1}^{n} Y_{ij} V_j \cos\left(\delta_i - \delta_j - \gamma_{ij}\right) \qquad (3)$$

$$Q_i = V_i \sum_{j=1}^{n} Y_{ij} V_j \sin\left(\delta_i - \delta_j - \gamma_{ij}\right) \qquad (4)$$

Limited number of DG units to be installed:

TABLE I
DATA OF CANDIDATE DG UNITS TO BE INSTALLED ON DISTRIBUTION SYSTEM

DG units data			
DG Cathegories	Total Cost of each unit	Capacity in KW	Total number of available Units
A	2500	5000	1
B	2200	4000	1
C	1800	3000	2
D	700	1000	6

III. GENETIC ALGORITHM

Genetic Algorithm (GA) was first introduced by John Holland in the early 1970's. They were designed to simulate processes in natural systems necessary for evolution; especially they follow the principles, which were first introduced by Darwin.

Overview of the GAs steps is as follows [10]:

At first step, population (t) is randomly created.

The fitness of population (t) is determined.

The following steps are repeatedly done until stop criteria is satisfied:

- Select parents from population(t)
- Perform crossover on parents creating population(t+1)
- Perform mutation on population(t+1)
- Determine merit of population(t+1)

Each population is composed of zeros & ones named chromosomes. They specify the behaviors of the population. After creation of individuals, they will enter into evolution process. Survival of each individual is dependent on his strength. Strongest individuals will have more chance to live. Genes of strong individuals propagate throughout the population so that two good parents will sometimes have children with better performance than their parents.

The algorithm involves three operators named as:

- Selection
- Cross over
- Mutation

A-Selection

Better individuals are more preferred, so they are allowed to pass on their characteristics to the next generation.

B-Crossover

Two individuals are chosen from the population using the selection operator. A Number of bits (genes) are randomly chosen from each parent and then the values of the selected bits are exchanged. Two newborn children will enter to the next generation of the population.

C-Mutation

Mutation is a chance given to the childes of weak parents for living. It means that the children of a weak couple might be a strong person in the future. Actually, it prevents the algorithm of being trapped into a local minima or maxima. For this reason, a portion of the new individuals must be selected with some low probability and then they will change some of their bits in random order. Note if the probability of mutation is chosen too high the search algorithm will change into a random search, which is not admissible.

IV. HILL CLIMBING ALGORITHM

The hill climbing algorithm was one of the first invented adaptive techniques along with the simple evolutionary strategies in the 1960s [11]. Hill climbers are individuals who try to improve their position independently. Like other heuristic search methods, hill climbing is an iterative process. The steps of the algorithm are as follows:

Step 1: An initial random solution is created.

Step2: The current solution is called x_C .

Step3: Another solution is found in the neighborhood of x_C , this solution is named x_n

Step4: x_C is replaced by the following probabilities:

$$\begin{cases} 1 & fitness\left(x_c\right) < fitness\left(x_n\right) \\ \dfrac{1}{1+e^{\left(\frac{fitness(x_C)-fitness(x_n)}{C}\right)}} & fitness\left(x_c\right) \geq fitness\left(x_n\right) \end{cases} \qquad (5)$$

Where:

Fitness: the amount of optimality of the solution

C: a parameter for convergence speed controlling

The process is repeatedly done until the stopping criterion is satisfied. The idea behind this algorithm is giving a chance to weaker solutions for survival [12]. That helps avoiding from being trapped to local optima.

II. PROPOSED ALGORITHM

Life Cycle Model (LCM) is a self-adaptive heuristic search algorithm in which each individual (containing the candidate solution) can decide whether it would prefer to belong to a population of a genetic Algorithm (GA) or become a Hill Climber (HC). The decision of them depends on their success in progressing toward the optimum solution of the objective function [13]. LCM consists of individuals starting out as GA individuals that can turn into Hill Climbers then back to GA and so on. The switching between stages occurs only when there is no improvement in objective function for more than 15 iterations. The steps of this model are shown in fig 1.

III. SIMULATION RESULTS

The present methodology was applied to two different distribution systems in order to demonstrate its applicability. In the studied cases, it is supposed that all buses are candidate for DG allocation. The GA algorithm Parameters used for all systems are as follows:
Population size: 100 individuals
Number of generations: 100
Crossover Probability: 85%
Mutation Probability: 2%

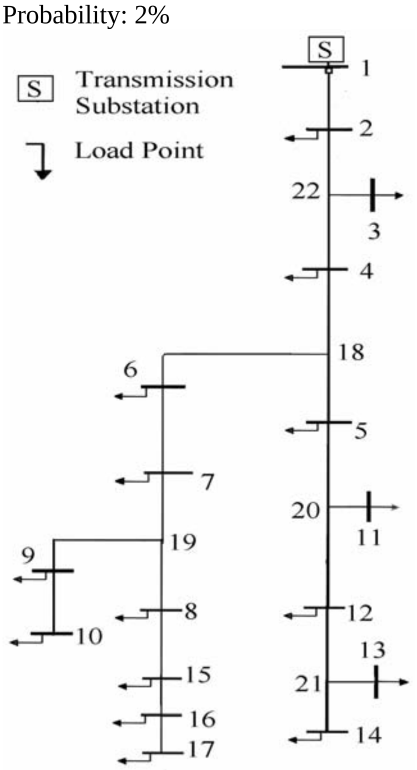

Fig. 2. Single Line Diagram of a 22-bus sample Distribution system

Fig 2 shows the single line Diagram of a 22-bus test distribution system. Fig 3 Sketches a comparison between objective function improvement of the proposed algorithm and simple GA. The optimal allocation obtained by simple GA and the proposed algorithm is shown in figures 4 and 5 respectively. Table II presents a numerical comparison of the percent of improvement between the proposed algorithm and simple GA.

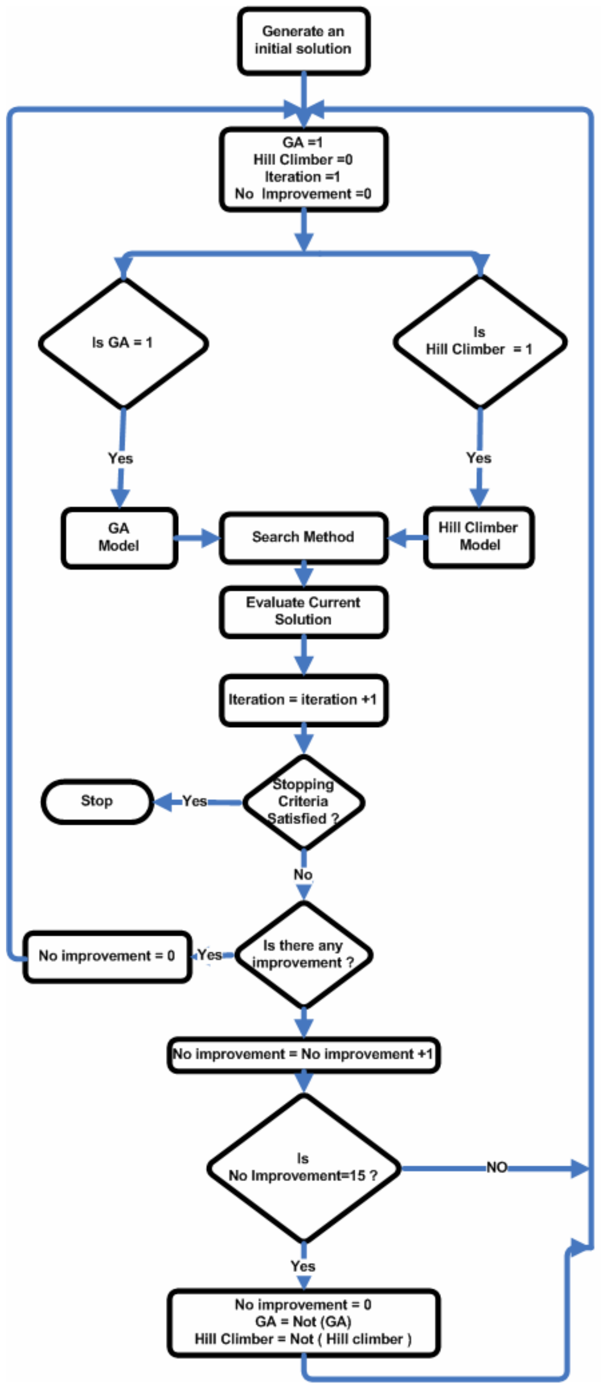

Fig.1. The steps of Life Cycle Model

Table II
Numerical comparison between the results of Life cycle and GA Model

22 bus system	percent of improvement %	final Costs ($)
Life Cycle Model	12.98	163423.89
Simple GA Model	10.35	168363.97
initial cost =	187807.29 $	

IV. CONCLUSIONS AND FUTURE WORKS

In this paper, a Life Cycle Model (LCM) is used to determine optimal placement of DG units. The advantages of this model over simple genetic algorithm are demonstrated by applying it on two test systems. Results presented in this paper indicate that the proposed algorithm can be used to find the optimal placement of DG units in a distribution system to reduce the active power losses and DG investment costs simultaneously. Future research will focus on defining a better objective function, which considers other potential benefits like reliability enhancements and working on how to use DG as a source of reactive power.

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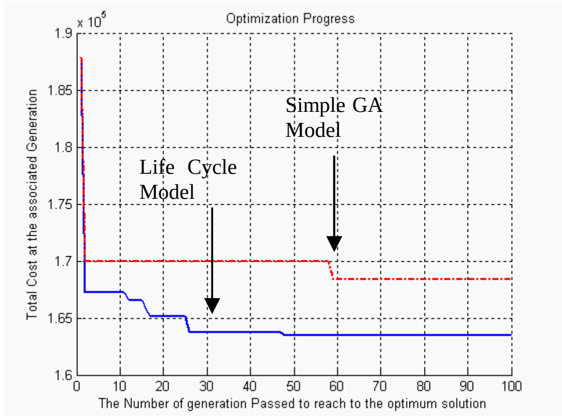

Fig. 3. The comparison between he results gained by simple GA and Life Cycle Model in sample distribution network

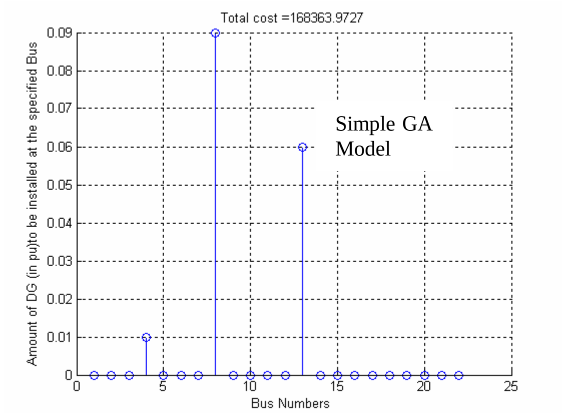

Fig. 4. The amount of DG to be installed in each bus in sample distribution network determined by simple GA

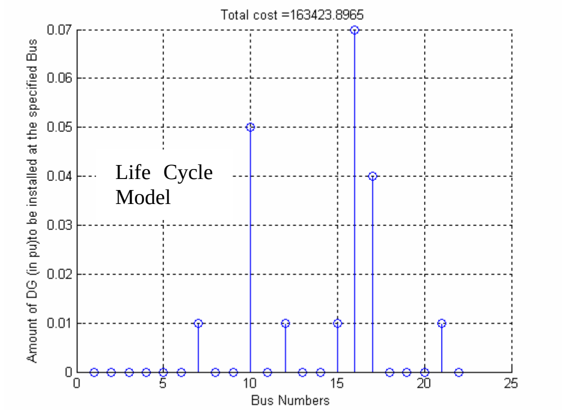

Fig.5. The amount of DG to be installed in each bus in sample distribution network determined by Life cycle model